Notified in Army Orders for July, 1942

THE WAR OFFICE

RESUSCITATION

EQUIPMENT, ORGANIZATION, TRAINING AND PROCEDURES 1942

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
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York House, Kingsway, London, W.C.2; 120 George Street, Edinburgh 2;
39-41 King Street, Manchester 2; 1 St. Andrew's Crescent, Cardiff;
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1942
Price 9*d.* net

By Command of the Army Council,

G. Brownrigg.

THE WAR OFFICE,
31*st July*, 1942.

CONTENTS

RESUSCITATION

EQUIPMENT, ORGANIZATION, TRAINING AND PROCEDURES

Since it is the policy of the Army to train a special medical officer at each Military Hospital, General Hospital, Casualty Clearing Station and Field Ambulance, in the ætiology, pathology and treatment of Secondary (syn. Traumatic, Hæmorrhagic, Wound) Shock, there are in this booklet some recommendations concerning the duties of this officer, the equipment needed, the personnel required to assist him and the organization he should endeavour to establish to enable him to carry out this important work. The officer should also refer to M.R.C. War Memorandum No. 1, produced in co-operation with the Army Medical Service, "The Treatment of Wound Shock" (H.M. Stationery Office, London).

GENERAL PRINCIPLES

The cardinal sign of *secondary shock* is a sustained or progressive lowering of the systolic blood pressure below 100 mm. Hg. This is exhibited after a period from one hour or longer by nearly all who suffer wounding in association with a considerable loss of blood. The reduction in blood pressure may be distinguished from that which is also found in *primary shock*, and which is then due to psychogenic and neurogenic influences, because the blood pressure in secondary shock is not restored by rest in the recumbent head-low position together with warmth and relief of pain by morphine. When casualties are seen soon after wounding, as is usual in air-raids, it is important to apply the simpler remedies first, before resorting to transfusion, unless the nature of the wounds makes it obvious that the patient must have suffered the serious reduction in blood volume which is the cause of the cardinal sign of secondary shock. Occasionally, the cardinal sign of depleted blood-volume, reduced blood-pressure, may not be as definite as would be expected in relation to the probable blood loss estimated from the degree of wounding. Thus, a hypertensive who has suffered gross loss of blood may still exhibit a blood-pressure within the recognized normal limits, whilst young subjects may, for a time, react to their blood loss with vasoconstriction intense enough to maintain a reasonable blood-pressure. These exceptional cases show the necessity for assessing all clinical features in addition to making blood-pressure observations. Restoration of the blood volume by transfusion is the most important single measure for the treatment of secondary shock; the sooner this restoration is effected the better are the results. In casualties with whom there has been a delay of more than a few hours, a lowered blood pressure always suggests the necessity for restoring blood volume by the transfusion

of a protein fluid—blood, plasma or serum. Crystalloid solutions such as saline or glucose-saline have only a temporary effect and when used alone invariably fail to restore blood pressure permanently. On the other hand, these crystalloid solutions are invaluable for the treatment of dehydration, which produces symptoms similar to those of secondary shock and is common in battle casualties (p. 37). In addition to a lowered blood pressure, other common signs of shock are a mentality that is alert, pallor and usually cyanosis of the nails or lips or both, sweating and thirst, with a tendency to vomit when fluid is taken by the mouth. Shocked patients, unless suffering from abdominal or head injuries, should nevertheless be encouraged to drink water, sweet tea or coffee. Such fluids not only contribute to blood volume but also assist in overcoming the tissue dehydration in casualties whose treatment has been delayed. Pain is often absent or comparatively slight in proportion to the amount of tissue damage. It is quite common for the pulse to be fast, but this is by no means constant and is not a reliable alternative guide to the condition of the patient. The volume of the pulse is more reliable than the rate. The importance of taking a blood pressure reading before judging a patient fit for operation cannot be overstated. Furthermore, a patient who has been successfully resuscitated may deteriorate while awaiting his turn for the operating theatre, or, as the result of an anæsthetic, or, by reason of the operation itself. It is therefore advisable for the resuscitation to be completed by the setting up of a bottle of blood, or other suitable protein fluid, administered by drip, which can accompany the patient to the theatre ; the rate of this transfusion can be varied according to changes in the patient's condition ; this also offers an opportunity for pentothal anæsthesia (p. 43). In restless patients the arm needs to be fixed with a splint. Persistent cyanosis is relieved by the administration of oxygen in adequate concentration, and facilities for this should be established whenever possible.

The admission of large numbers of casualties into any hospital calls for a ward where shocked patients may be quickly and skilfully attended. Routine work in permanent hospitals often makes it impossible to set aside a special ward in waiting, but all hospitals should have chosen such a site, have assembled all the necessary equipment and have appointed a staff who are fully conversant with the work that has to be done. Under active service conditions the majority of resuscitation work takes place at Casualty Clearing Stations and here the organization should be highly developed. In relatively quiet periods there is opportunity for this work in a Field Ambulance. A scheme for the general administration of a resuscitation ward is given below. The scheme is based on experience gained at Casualty Clearing Stations during the Dunkirk campaign, 1940, and during air raids on Britain.

ADVANTAGES OF A RESUSCITATION WARD

A properly equipped and staffed resuscitation ward ensures that all patients requiring urgent treatment receive it with the minimum of delay and in the best surroundings.

The reasons for this are :—

1. From the moment of the patient's arrival in the ward, the staff know what to do and how to go about it.

2. There is no delay in obtaining apparatus, as it is all in the ward.

3. Heating systems may fail. Emergency measures can seldom embrace several wards at once, but it is simple to heat one ward and to have means for rapidly warming the very cold patients.

4. Response to treatment can be more acutely observed ; this may enable life-saving measures to be adopted at the right time.

5. It allows a proper control over the arrangements for giving intravenous fluids. The whole system of resuscitation depends on close co-operation between those in charge of blood and other supplies of transfusion fluids and those administering them. There are times when it is difficult to obtain such fluids, and a knowledge of all the working arrangements of the system is essential for the medical officer in charge of the ward, to ensure maximum benefit for the largest number of cases.

RESUSCITATION WARD

Size

Experience shows that approximately 15 per cent. of casualties require resuscitation treatment. The ward selected should therefore be of such a size as to accommodate this proportion of the total number of casualties which could on any one occasion be admitted to the hospital. Hospitals which are especially likely to receive air-raid casualties should make a somewhat more generous allotment of space, because many who are brought quickly from the scene of a raid are still suffering from primary shock. Such patients should be admitted to the resuscitation ward for treatment with simple measures. Primary shock can then be clearly differentiated from secondary shock, and those who drift into the latter condition be treated without delay.

Site

The ward should be large, solidly built, easily heated, devoid of draughts, quiet and near to both the reception department and the operating theatre. When these last two conditions cannot be satisfied it is preferable to site the ward near the operating theatre, as patients have often to be followed into the theatre with a transfusion in progress. The windows should be bricked up ; work in the ward will not then be disturbed by the shattering of windows nor rendered difficult by cold. Ventilation according to local facilities and conditions must be provided. Emergency lighting and heating should be arranged, in case of failure of central sources.

Lay-out

In permanent hospitals a ward, holding twenty or more beds, should be equipped with trolley-screens. Males should be placed at one end, females at the other and the screens moved up and down according to the sexes. Air-raid experience shows that the number of male casualties is usually greater than female, and this

should be borne in mind when the shape of the ward necessitates one part being bigger than another. It is inadvisable to move the severely injured more than is necessary ; most cases do best if the only move is from the stretcher to the operating table. The ward should not, therefore, be filled to capacity with beds. Ample room should be left for stretchers on the floor and on trestles. Beds should be prepared with a loose canvas cover, a mackintosh sheet

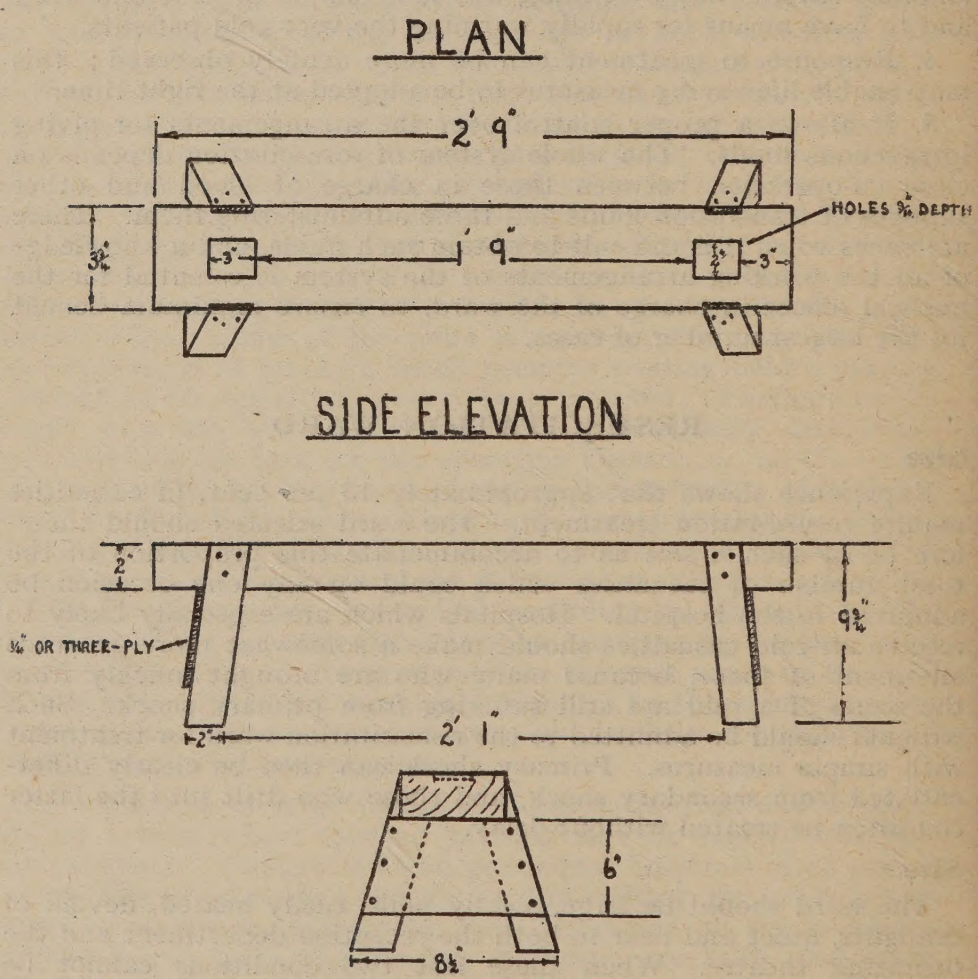

FIG. 1.

Stretcher trestle-block.

and a blanket ; hot-water bottles can be placed beneath the blanket ; top blankets should be obtained, when needed, from a hot air cupboard ; sheets are undesirable. If necessary the patient can be lifted on to a trolley by means of the canvas cover. Many wards have a single-bedded room nearby, which should be fitted with a table, good light, facilities for scrubbing and the means for giving a general anæsthetic. Such a room is useful for the bleeding

of donors and for the treatment of special cases. If a room is not available, then a portion of the ward should be screened off for these purposes. With units on active service provision must be made for treatment of cases upon stretchers. Trestles should be placed to receive the stretchers in the places ordinarily occupied by beds, but a certain amount of floor space should be left for the reception of stretchers at floor level. Trestles should be made in two sizes, one having legs five inches higher than the other in order to allow the patient to be tilted head downwards. The two sizes of trestle should be clearly marked to distinguish one from the other. For stretchers on the ground, trestle-blocks with slots to receive the runners are extremely useful (Fig. 1).

Personnel

The *resuscitation officer* must be given full control of the patients in the ward and his advice should be accepted by the surgical teams, with whom he must collaborate closely. It is therefore essential that he be a medical officer of some experience, preferably a physician. Selection of cases for treatment in the ward will vary according to the unit. Whatever arrangement be in force, the resuscitation officer must maintain close liaison with the reception officer, who should also be an experienced medical officer, since he will decide which patients are to be admitted to the resuscitation ward. An understudy is always advisable and he should be available to assist during peak periods. The resuscitation officer and his understudy should be fully conversant with the treatment of gas casualties.

In a C.C.S. the resuscitation officer is always the O.C. of the Field Transfusion Unit. He should depute and train an understudy from among the general duty medical officers of the C.C.S., to be ready to assist him or take his place.

Nurses or orderlies should be allotted in the proportion of one per four beds. In a C.C.S. two orderlies of the Field Transfusion Unit form the nucleus of the resuscitation ward staff, but other general duty orderlies should be trained in this work and be available as supplements.

TRAINING OF NURSES AND ORDERLIES

The resuscitation officer is responsible for training the staff to a high state of efficiency, so that all understand the main essentials of the work and are fully conversant with the general arrangements of the ward.

Instruction should be given on the following matters :—

(1) The immediate care of the wounded on admission, including the systematic recording of all facts of importance to the resuscitation officer (p. 11).

(2) The preparation of a patient for transfusion, including immobilization of a transfusion limb.

(3) Care and maintenance of all equipment in the ward in a state of readiness, especially the cleaning, reconstruction and sterilization of all apparatus for giving intravenous fluids, including blood (p. 34).

(4) *Stored Blood.*—Survival period and recognition of hæmolysis ; criteria of fitness for use ; storage conditions ; warming of blood before use (p. 26).

(5) *Plasma.*—The keeping properties and storage conditions of plasma ; criteria of fitness for use, such as presence of clots and turbidity (p. 29).

(6) *Dried Plasma and Serum.*—Keeping properties ; reconstitution and administration (p. 30).

(7) *Glucose-Saline.*—Administration (pp. 31,38).

(8) The duties of an assistant at a transfusion ; assembly and preparation of all necessary apparatus and instruments, control of rate of flow, removal of needle or cannula and after-care of limb.

(9) The recognition and treatment of a mis-matched transfusion and other less serious reactions (pp. 32, 33).

(10) The determination of blood pressure and pulse rate. Distinction between volume and frequency of pulse.

(11) The use of surgical instruments, oxygen cylinders and masks, sedative and stimulating drugs, bed blocks, trestle-blocks (Fig. 1) and stretcher trestles.

(12) The special procedures or observations necessary on the admission of a patient, *e.g.*, chest and head injuries not to be placed in the head low position until seen by an officer ; clothing to be cut off with the minimum of manipulation of injured parts ; observation of the amount of bleeding ; the uses and dangers of the tourniquet (p. 40) ; application of warmth ; administration of warm, sweet drinks (tea, coffee, lemonade) to all conscious patients not suffering from penetrating abdominal wounds or head injuries (p. 39).

For active service units a knowledge of the care and maintenance of a refrigerator is also essential.

The exact procedure in a resuscitation ward will be evolved according to the ideas of the resuscitation officer, but arrangements or rules made must be efficiently taught to the staff, so that they can carry them out rapidly and efficiently without close supervision.

During the instruction courses frequent " drills " should be held in which an increasing number of wounded patients are admitted to the ward. In this way the staff will become familiar with their duties and thoroughly proficient. Drills should be arranged in which the ward is dismantled and set up, so that the staff may learn the necessity of the careful setting out of apparatus and that each piece has an allotted position. When proficiency in both these drills has been acquired they may be combined in one exercise, the ward being first set up, and this being followed by the admittance of a series of dummy casualties. Drills under conditions of emergency lighting, and when wearing protective clothing and respirators, are also valuable.

GENERAL DUTIES OF A RESUSCITATION OFFICER

The resuscitation officer should grade the patients admitted into various categories according to the degree of their injuries as well as their urgency or fitness for operation. The following scheme is given as an example :—

Category	*Classification*
Head wounds, penetrating chest and abdominal wounds	xxx
Compound fractures and multiple gun-shot wounds	xx
Isolated limb injuries	x

A chart should be kept, showing time of admission, nature of injuries, classification sign and a space for inserting the letter O when the patient is considered fit for operation. Each patient may be given a number against his name, which should be prominently displayed on his chart and also inserted on the coloured label which should be tied to him when receiving treatment in a resuscitation ward. When the patient is transferred to another part of the hospital this label should be attached to his bed, so that the resuscitation officer may follow up his cases without delay.

It is a good arrangement for the surgeon of each surgical unit to visit the resuscitation ward at least once in four hours. He should be shown the classification charts, which will allow him to choose his cases to the best advantage. Time is also saved by visiting only those whom the resuscitation officer has marked as fit for operation. If casualties are very numerous this method of orderly selection may not be possible, and in these circumstances the surgeon and resuscitation officer should make their selection together.

Once agreement has been reached as to the order and number of cases to be operated upon, every effort must be made to ensure a continuity of operations. The resuscitation officer should set up all transfusions himself unless he knows that an assistant is an adept at this procedure. Inexpert help in this respect wastes more of the officer's time than if he had himself carried out the procedure from the outset.

GENERAL DUTIES OF NURSING STAFF

In preparation for the reception of casualties the ward should be set out and a plentiful supply of warm blankets prepared in advance.

The nurse or orderly admitting a case should immediately inquire whether the patient has a chest or head injury. If the bearers do not know, the stretcher should be placed on the floor pending examination of the patient's card or his examination by the resuscitation officer. Cases of chest and head injuries, as well as cases of severe shock without visible signs of injury, should be left lying flat until examined by the officer. All others should, as a routine, be placed in the head low position either in beds or on stretchers with the foot raised by blocks (Fig. 2), or on trestles or, if stretchers on the floor, on trestle blocks (Fig. 1). Restless patients should

not be put on trestles. Movement is to be discouraged. Common sense and experience will dictate which can be moved from stretcher to bed and which are better left undisturbed. An injured limb should not be moved unless the need is urgent. A tourniquet should be looked for, but must on no account be removed without the sanction of the officer ; nor should a tourniquet be applied unless the need is urgent. If known, the time at which a tourniquet was applied should be recorded on the patient's chart, and a note made of the amount of blood on a stretcher, a watch being kept to see that this does not increase to a dangerous extent. Morphine has almost always been administered to casualties before admission to a resuscitation ward, the record card being marked with the dose and time (or sometimes the patient's forehead). When no morphine

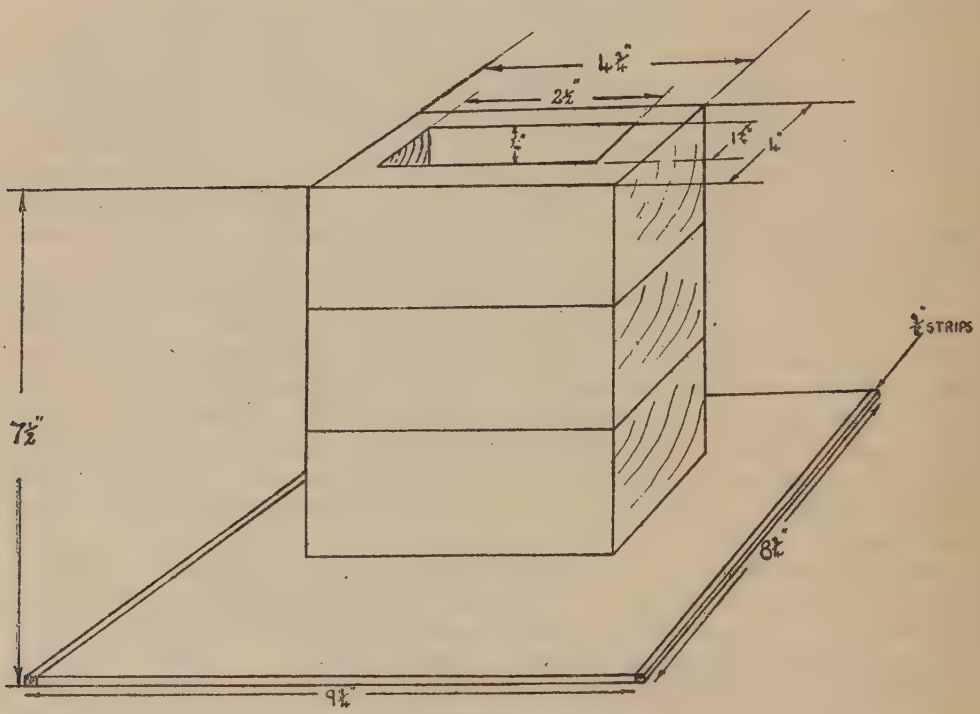

Fig. 2.
Bed block.

has been administered, or when the time interval exceeds four hours, a syringe should be loaded with a dose to be given at the time of the officer's examination or at his direction. Having completed these preliminary examinations no time should be lost in removing the clothing and getting the patient covered with warm blankets supplemented by whatever warming arrangements are available (p. 16). When clothing cannot be removed without causing pain or undesirable movement it should be slit at the seams with a strong pair of scissors (carpet fitter or paper-hanger type). Stretcher cases should have the blankets folded and wrapped according to R.A.M.C. Training (1935), Section 74. This method, in principle, ensures that the patient has sufficient protection underneath as well as on top and allows of free access for examination.

Note must be made of the rate and volume of the pulse. Quite often the rate can only be determined by using a stethoscope and counting the apex beat. If the patient has an uninjured arm the clothing should be slipped off or cut off and a sphygmomanometer cuff applied. The instrument itself can then be plugged in and the blood pressure recorded by the officer or some other person delegated by him. Spare cuffs greatly facilitate this important side of resuscitation work and reduce the amount of disturbance to the patient. If the patient is conscious, and not suffering from abdominal wounds or head injuries, he should be encouraged to take warm drinks. Large gaping wounds should have gauze soaked in acriflavine applied to them. Wounds must not be bandaged until seen by the officer. Those in charge of patients should make it their business to see that the resuscitation officer examines the case with the minimum of delay and that all relevant points elicited by him are properly recorded.

When a transfusion is ordered all the apparatus should be immediately collected. Conscious patients should be sympathetically told what is going to be done, with emphasis on the necessity for keeping the arm still. The arm should be fully extended, with a support under the wrist and the hand kept covered and warm. Restless patients need to have the arm held in a splint. During the transfusion the attendant is responsible for seeing that the fluid runs in at the proper rate. The volume and rate of the pulse should be recorded every fifteen minutes, and the resuscitation officer informed of any deterioration in the patient's general condition. When the transfusion is complete the apparatus should be screwed off and the officer informed, so that he may judge whether more should be given or whether other treatment is required. A patient sent to the theatre with a transfusion in progress should be accompanied by an attendant. The attendant must be conversant with the signs and symptoms of mis-matched transfusion and other less serious transfusion reactions (pp. 32, 33). A mismatched transfusion should be stopped immediately and a report made to the officer.

EQUIPMENT

The equipment of a fixed hospital is obviously more elaborate than that of a Field Transfusion Unit on active service, but the lists set out below provide a choice according to local facilities and supplies. It is essential to assemble all small equipment, drugs, etc., in cupboards so that all the staff know where everything is kept. Every hospital should allot a room where donors can be bled and where all the apparatus required for the bleeding (pp. 25, 31) should be kept.

1. Intravenous Fluids

Stocks of protein-containing intravenous fluids (blood, plasma, serum) should be based on an estimate that each case may require one to one and a half litres for efficient treatment. Stocks of durable fluids (plasma, serum) or dried products should not be depleted for isolated cases. A blood donor should be procured as in ordinary peace time conditions. A stock of isotonic glucose-saline (p. 31), estimated at one litre for each one per cent. of cases,

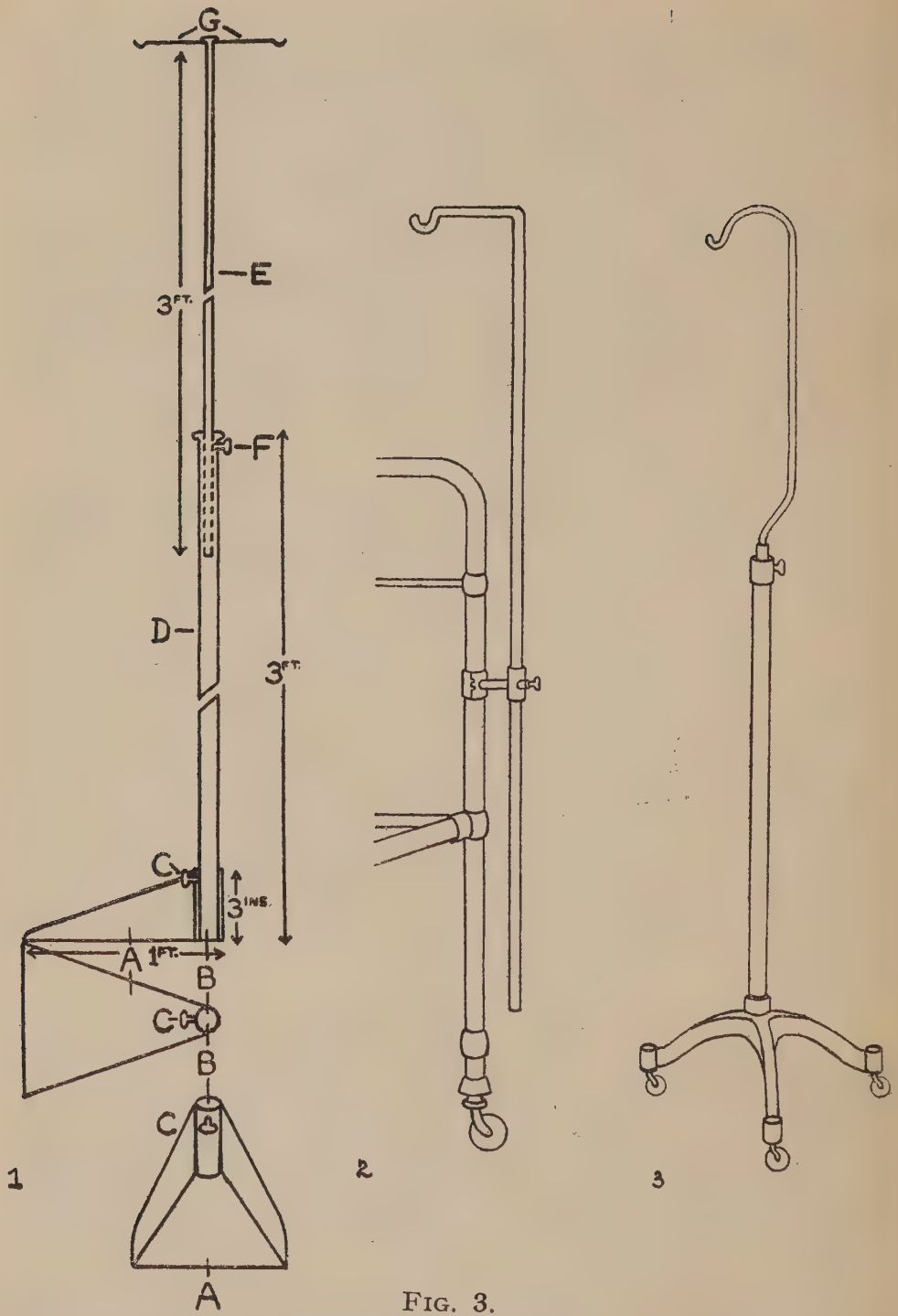

FIG. 3.

Various stands suitable for transfusion work. (1) Standard army telescopic stand issued to Field Transfusion Units (A—foot-plate; B—socket for receiving first section; C—clamping screw; D—first section; F—clamping screw; E—second section; G—double hook).

(2) Bed pattern (Chas. F. Thackray, Ltd.). (3) Movable ward pattern (John Bell and Croyden).

should also be kept. There should be an adequate supply of pyrogen-free distilled water (p. 34) distributed in bottles of convenient size for dissolving up dried products. On active service, and specially in tropical countries, by reason of the frequency with which dehydration occurs, the stock of glucose-saline should be estimated on a basis of one litre for each five per cent. of casualties.

2. Equipment for Administering Intravenous Fluids

Each bottle of protein-containing intravenous fluid should be accompanied by a separate packet containing the sterilized equipment for administration to the extent of one set for each two 500-c.cm. bottles. Glucose-saline stocks should be equipped with one set for each 500-c.cm. bottle.

Stands from which transfusion bottles can be suspended to the extent of 25 per cent. of beds are essential unless the beds are already provided with a suitable bracket. Figs. 3 and 3A illustrate four types of suitable stands.

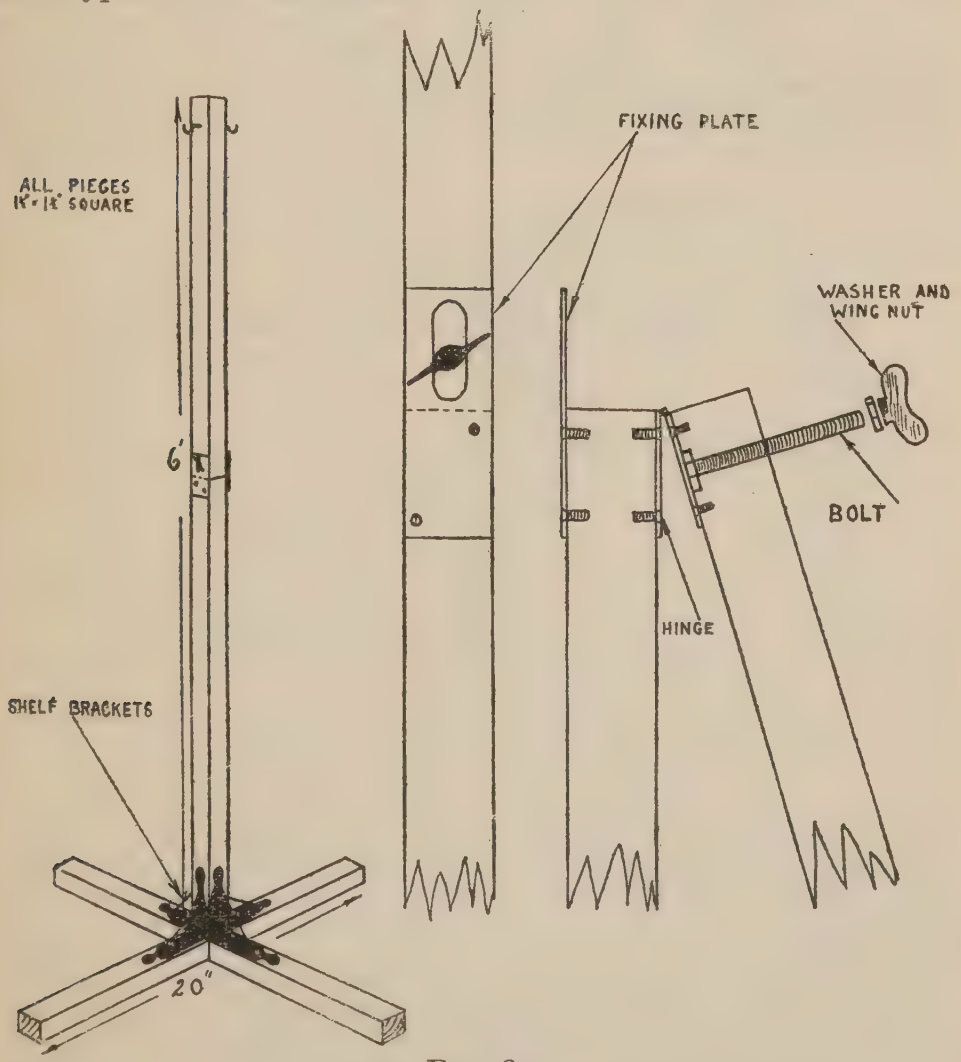

FIG. 3A.

An easily made folding stand.

Facilities for warming blood should be arranged. On active service this is done in a bucket of warm water.

Permanent hospitals should supplement this equipment with :—

(*a*) Apparatus for rectal saline administration—two or three sets.

(*b*) Apparatus for subcutaneous saline—two or three sets.

(*c*) Equipment for the taking of blood (p. 25).

(*d*) Apparatus for administration of fluid by stomach drip.

3. General Equipment

Trolley screens, bed blocks (Fig. 2), stretcher trestles (of two sizes, so that the head is five inches below the feet, stretcher trestle-blocks (Fig. 1) ; lighting apparatus, to include head lamps and hurricane lamps. Back rests (approximately ten per cent. of beds), limb splints, mackintosh sheeting, urinals and bedpans. Small sterilizers or small saucepans (8-in. × 4-in. deep) with sieves, complete with lids, for the boiling of small instruments. Well-equipped hospitals may provide themselves with large containers for drinks, to be suspended above each bed, from which the fluid is fed to the

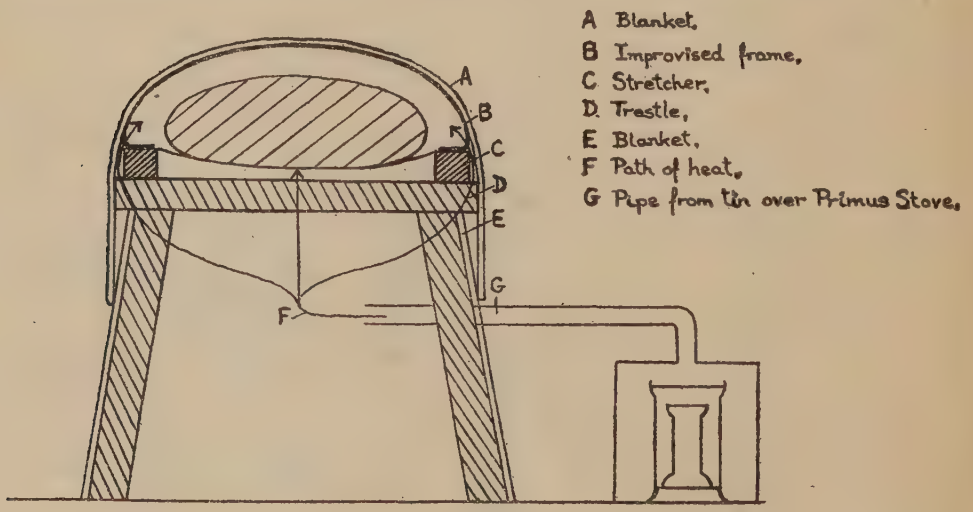

FIG. 4.

Warming apparatus made with a Primus stove.

patient by a rubber tube with an end piece that can be changed. Large kettles for the making of warm drinks should be available, also a number of Primus stoves in case of failure of gas or power.

Facilities for warming patients are essential. These range from improvisations with a Primus stove, as described in R.A.M.C. Training (1935), Section 231 (Fig. 4), to electric cradles and elaborate thermostatically-controlled electric blankets. Whatever resources are available, there should always be a generous supply of hot-water bottles as well. Oil stoves as an emergency stand-by are valuable for heating the ward.

4. Surgical Equipment

Simple instruments for cutting down on a vein ; instruments for arresting hæmorrhage, including tourniquets ; instruments for the immediate closure of thoracic wounds, together with a plentiful supply of ligatures, bandages, gauze, dressings, elastic plaster, zinc oxide plaster, bowls, receivers and syringes (2 c.cm. and 5 c.cm.) with fine needles. This, and much of the medical equipment, should be assembled in complete sets and then distributed on trolleys. Each attendant should be equipped with a pair of carpet fitter's scissors (or scissors, stretcher bearer) for the cutting of clothing. A list of equipment carried by a Field Transfusion Unit on active service is given on p. 20. Here the equipment is disposed in a special box with divisions and trays (Figs. 5, 6, 7) movable from stretcher to stretcher ; the box takes the place of a trolley.

5. Medical Equipment

Clinical thermometers, Higginson's syringes (for the exerting of positive pressure when administering intravenous fluids) ; sphygmomanometers, with a plentiful supply of spare cuffs ; Ryle's duodenal tube.

B.L.B. masks (Fig. 11) for the administration of oxygen are an essential piece of equipment, together with flowmeters, reducing valves, cylinder pressure gauges and oxygen cylinder with keys and containers for same. In large hospitals oxygen can be piped to each bed from a central source of supply.

6. Drugs and Comforts

Surgical spirit ; acriflavine 1 in 1,000 in liquid paraffin ; local anæsthetics—procaine two per cent. ; morphine solution conveniently in rubber capped bottles gr. $\frac{1}{4}$ to ℿ.x. ; atropine sulphate in solution conveniently as gr. 1/100 to 1 c.cm. ; adrenalin ; nikethamide (coramine) ; Dettol-type or other suitable surgical antiseptic ; tetanus and gas-gangrene antitoxin ; sodium bicarbonate solution (one drachm to the pint) for irrigating burns of the eyes ; atropine ointment one per cent. ; ointment, anti-gas No. 2 ; bleach ointment ; one per cent. copper sulphate and other requisites for the immediate treatment of gas and phosphorus burns ; sulphanilamide tablets for use, at the discretion of the officer, for the oral prophylaxis of wound infections ; sodium citrate solution (gr. 60 to the ounce) for the treatment of mismatched transfusions (p. 32).

Brandy, tea, coffee, lemonade, bovril, marmite (sugar and salt to be added to all drinks).

7. Field Transfusion Unit

The following list shows the surgical, medical, drug and general equipment carried by a Field Transfusion Unit on active service when attached to a Casualty Clearing Station. The list of instruments may be accepted as the minimum required for resuscitation work on organized lines.

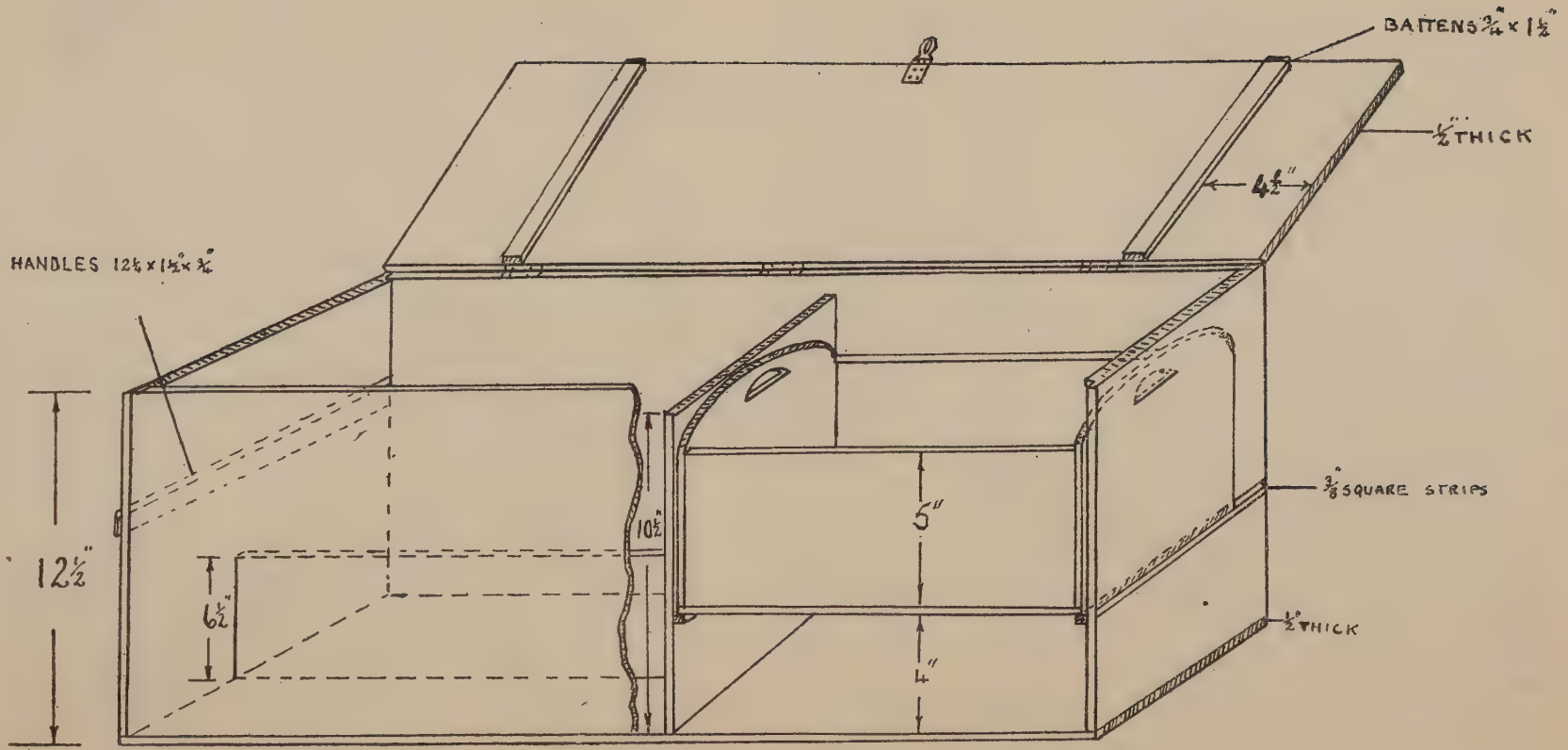

FIG. 5.

Equipment box for Field Transfusion Unit.

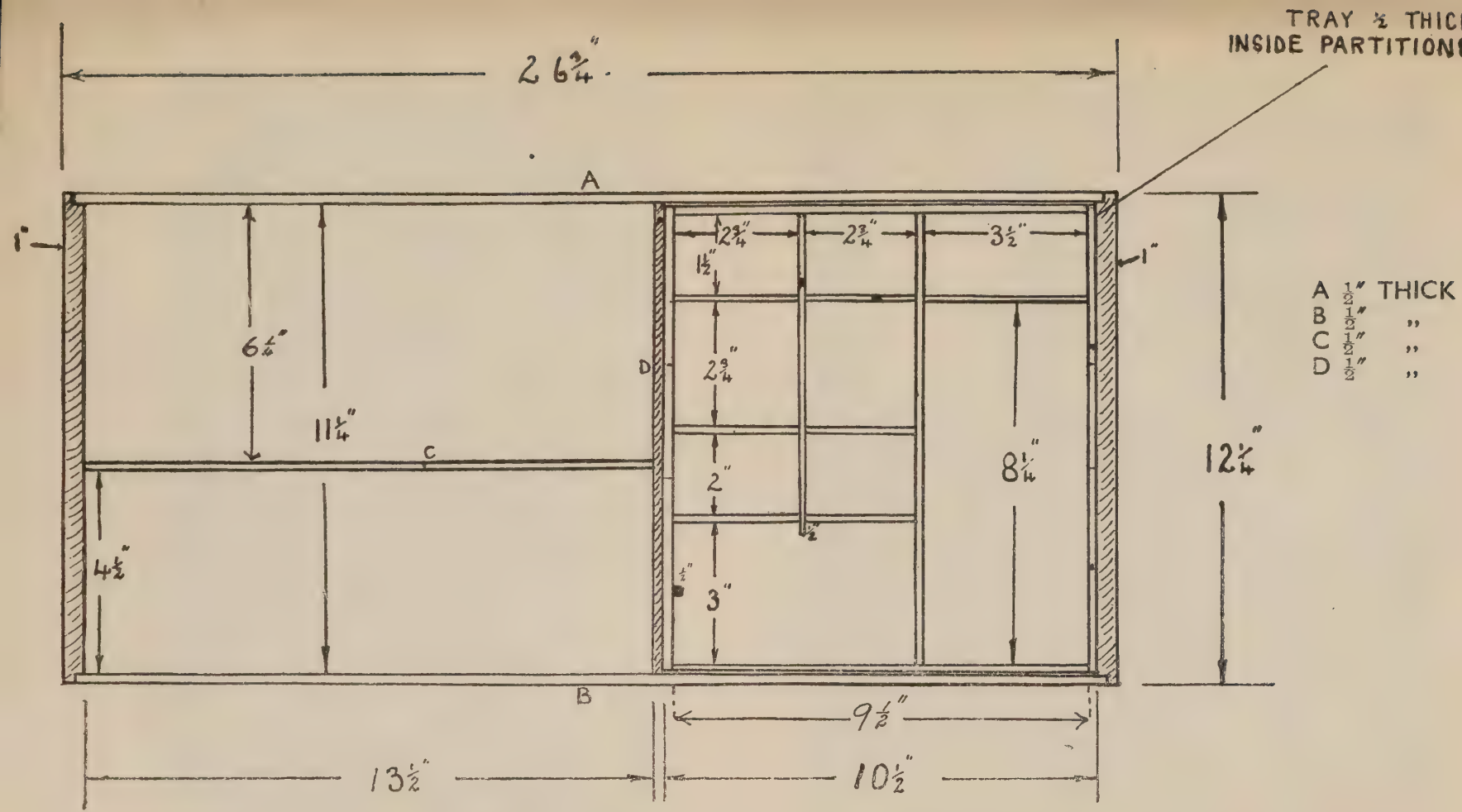

FIG. 6.

Plan of equipment box for Field Transfusion Unit.

Section I (A)

Acriflavine, 0·1 per cent., in liquid paraffin, 4-oz. bottles	no.	1
Aqua destillata, 4-oz. bottles, rubber capped, sterile	no.	1
Atropine sulphate solution, 1/100 gr. in 1 c.cm., in 2-oz. bottles	no.	1
Glucose saline, in pint bottles	no.	50
Morphine injection, 1½ oz. in 2-oz. amber-glass bottles	no.	2
Nikethamide, 2 c.cm. ampoules, in boxes of 6 ampoules	ampoules	24
Procaine and adrenaline (self-sterilizing) 3 per cent. solution in 2-oz. bottles	no.	2

Section I (B)

Plasma, fluid, with giving sets, in bottles	bottles	100
Serum, dried, Grouping, ampoules 2 c.cm.	prs.	5

Section II

Tablets, sulphanilamide, 0·5 g.	no.	50

Section III

Bandages, elastic plaster, 1 in. × 3 yds.	no.	1
,, open wove, bleached, 3 in × 4 yds.	no.	10
Gauze, absorbent, bleached, 6-yd. packets	pkts.	1
Lint, cotton, absorbent, 4-oz. packets	pkts.	2
Wool, cotton, absorbent, 4-oz. packets	pkts.	2

Section IV

Sheeting, waterproof, india-rubber, red, 36 in. wide	yd.	1

Section V (A)

Apparatus, oxygen, B.L.B., Field Pattern, complete	no.	2
Basins, dressing, enamelled iron, kidney-shaped, 6-in.	no.	2
Bowls, dressing, enamelled iron, round, 8-in.	no.	2
Catgut, sterilized, 20-day, size O	tubes	12
Cylinders, oxygen, full 40 cu. ft.	no.	2
Enemas, india-rubber, with vulcanite nozzle, complete	no.	2
Needles, suture, blunt point, straight, 1½-in.	no.	2
,, ,, curved, 1½-in.	no.	1
Plaster, adhesive, zinc oxide, 1 in. × 10 yds.	spools	2
Silk, suture, No. 2	oz.	2
Stands, Blood Transfusion, adjustable	no.	6
Stones, needle sharpening	no.	1
Tourniquet, Samway's, Max Page modification	no.	2

Splints and Appliances for Making

Pliers, wire cutting, for Cramer splinting	no.	1
Splinting, wire, Cramer, 60 c.cm. × 8 c.cm.	pieces	3

[*To face p.* 20

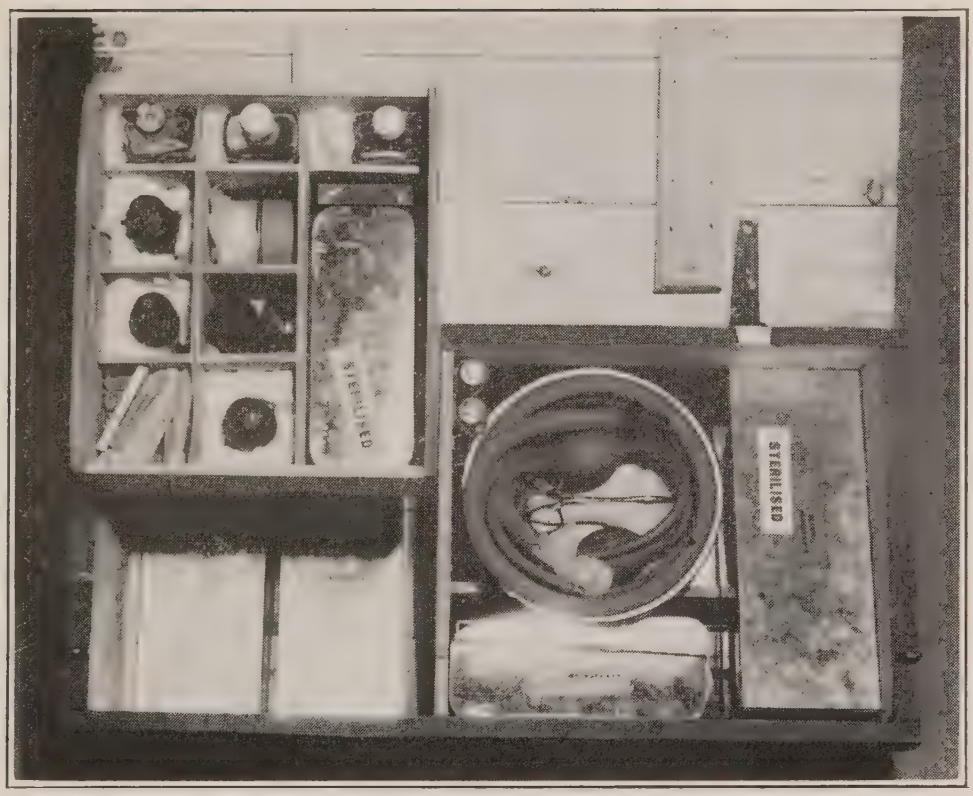

FIG. 7.

Equipment box for Field Transfusion Unit showing disposition of equipment.

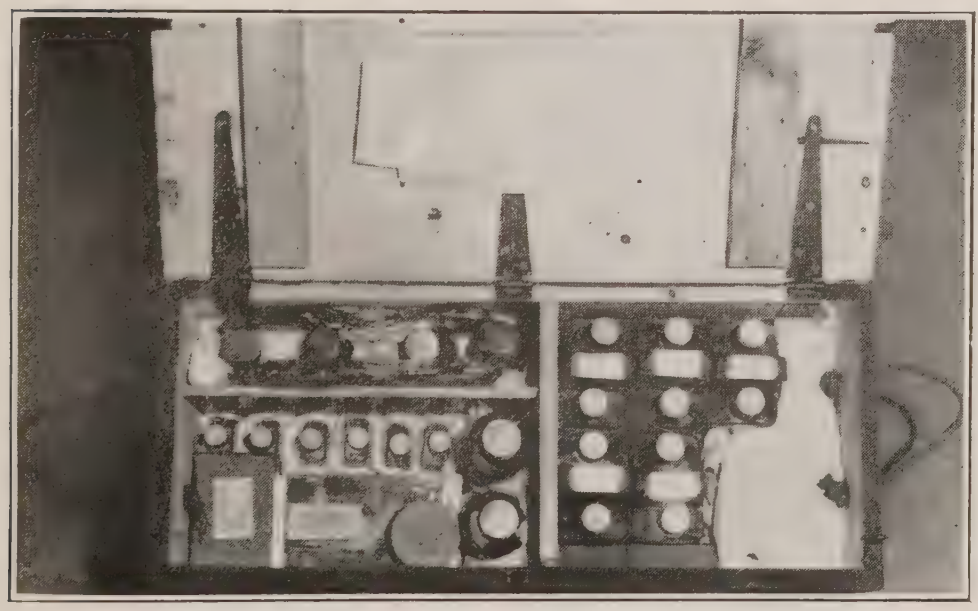

FIG. 8.

Army Blood Supply Depot Field Pattern Box for use by Field Ambulances, Troopships and small isolated medical units.

Section VI

Forceps, artery, Halstead, fine, curved, 5-in.	no.	2
,, ,, Spencer Wells, 5-in.	no.	2
,, dissecting, fine points, 5-in.	no.	1
,, ,, toothed, 5-in. (fine, 2/1)	no.	1
Giving sets, for glucose-saline, complete	no.	25

Each set consisting of :—

I.R. bung with 2 glass tubes, drip indicator, air filter, intravenous needle and adaptor, screw clamp and necessary I.R. tubing.

Knives, Bard Parker type, handles for, size 4	no.	2
,, ,, ,, blades for, No. 20	no.	6
Lamp, head, electric, " Ever Ready," with condenser, complete	no.	1
Lamp, head, electric, batteries for	no.	1
,, ,, ,, lamps for	no.	1
Needles, aneurism, curved, small	no.	1
Scissors for blood transfusion, blunt-pointed fine	no.	1
Sphygmomanometer, " Accoson," mercurial, pocket model, complete in case, with canvas cover	no.	1
Ditto, armlets for	no.	2
Ditto, bellows for	no.	2
Sterilizer, fish kettle, pannier pattern, complete with lamp	no.	1
Syringe, hypodermic, 2-c.cm., needles for	no.	12
,, serum, " Record," 5-c.cm. with two steel needles, in case, complete	no.	2
Taking and Giving sets, with screw-cap bottles (1940 pattern), complete	no.	2

Each set consisting of :—

Bottles, blood transfusion, screw-cap, sterile, empty	no.	2
Bottles, dispensing, plain, screw-cap, 4-oz., containing solution of sodium citrate, 3 per cent. 100 c.cm.	no.	6

Sets for blood taking, sterile, consisting of :—

I.R. bung with 2 glass tubes, air filter, 1 piece of glass tubing, intravenous needle, and necessary I.R. tubing	no.	2

Sets for blood giving, sterile, consisting of :—

I.R. bung with 2 glass tubes, drip indicator, air filter, intravenous needle and adaptor, screw clamp, glass beads and necessary I.R. tubing	no.	2
Cannula, intravenous	no.	1
Spare glass beads	lb.	¼
Box, cardboard, to contain same	no.	1
Directions for taking and giving blood	no.	1

Section XI (A)

Crates, wire, to hold 10 bottles, Plasma Fluid ..	no.	10
,, ,, ,, 10 bottles, Glucose Saline ..	no.	5

Section XIII

Box, wooden, $24\frac{3}{4} \times 12\frac{1}{2} \times 12\frac{3}{4}$ in.	no.	1
,, tin, $8 \times 3 \times 1$ in. for swabs (A.B.S.D.)	no.	4
,, ,, $11 \times 3\frac{1}{4} \times 3\frac{3}{4}$ in. (A.B.S.D.)	no.	4

SUPPLIES AND COMMUNICATIONS

The Army Organization for the supply of transfusion fluids and equipment consists of :—

Army Blood Supply Depot (Home).
Base Transfusion Unit (Overseas).
Field Transfusion Units (Home and Overseas).
Supplies to Field Ambulances, troopships and other isolated units.

Army Blood Supply Depot (Home)

This large central organization is intended to supply, mainly through Field Transfusion Units (Home and Overseas), the whole army, at home and abroad, with all equipment, with grouping serum and with all transfusion fluids that cannot be obtained locally. Plasma and serum, fluid or dried, are always obtained from this source. Blood is supplied to R.A.M.C. units within road or air delivery distance of the depot if they are unable to obtain blood by means of their own local organization. Glucose-saline is supplied to units which have no facilities for preparing their own. The depot is also the training school for resuscitation work and carries a staff of skilled engineers for the repair and servicing of all army refrigeration apparatus.

Base Transfusion Unit (Overseas)

This is attached to the Base Pathological Laboratory of an overseas force. According to distance, this base unit is either largely self-supporting or obtains most of its supplies by air or sea transport from Army Blood Supply Depot (Home). The unit has facilities for the preparation of simple intravenous fluids, such as glucose-saline, and it carries a staff of engineers for refrigerator-servicing and repair. The main function of the base unit is to maintain supplies at forward units, *e.g.* L. of C. hospitals, C.C.Ss. and Field Ambulances. The base unit is furnished with a pool of mobile Type A refrigerator vehicles (p. 45) with which to establish intermediate depots further forward, should communications become lengthened.

Field Transfusion Units (Home and Overseas)

Field Transfusion units are Field Force units, self-contained with their own medical mobilization scales and war equipment tables.

At home they are normally allotted areas on a geographical basis and come under the orders of the senior administrative medical officer of the area in which they are located. In such an area the Field Transfusion unit officer is responsible for all the technical duties connected with transfusion and resuscitation and for the instruction of personnel in all matters pertaining to these subjects. In commands the A.D.P. acts as the command transfusion and resuscitation officer (in addition to his other duties) and is responsible for the co-ordination of all matters connected with this subject including the technical direction of Field Transfusion unit officers within the command. The Field Transfusion unit is responsible for the resuscitation arrangements in the medical unit to which it is attached but is at the disposal of the O.C. this medical unit when not employed on these duties. The duties of an O.C. a Field Transfusion unit include : (1) the keeping of A.D.P. informed of all matters connected with transfusion and resuscitation in the area allotted to him, (2) the supervision by monthly inspection, and, maintenance, of a reasonable and adequate supply of transfusion fluids in all suitable medical units with an organization for replenishment in case of active operations, (3) the provision and supervision of supplementary dumps of transfusion fluids in places convenient for local needs, (4) the formation and maintenance of local donor panels in suitable medical units, (5) the bleeding of local donors and carrying out of transfusions in the unit to which he is attached, (6) the continuous training of his own unit by means of frequent drills, (7) the institution of schemes of instruction and training in Field Ambulance and other units so that officers and men are familiar with simple resuscitation methods and transfusion equipment, (8) the maintenance of close liaison with civilian transfusion services so that mutual assistance may be possible with regard to personnel and supplies.

The nursing orderlies on the strength of a Field Transfusion unit require to be fully trained in all procedures ; for this a qualifying examination is held at the Army Blood Supply Depot ; they require also to be trained in the elementary principles of refrigeration, the maintenance of a refrigerator, the execution of small running repairs. The R.A.S.C. driver attached to a Field Transfusion unit needs to be trained in the servicing, operating and maintenance of a refrigerator in addition to his normal duties.

When Overseas.—A Field Transfusion unit is normally attached to a C.C.S. where, on active service, the majority of resuscitation work is carried out. The unit is, however, at the disposal of the senior administrative officer, for posting to any place according to local conditions. Supplies are maintained by communication with the Base Transfusion unit or with the nearest intermediate sub-depot.

Field Ambulances, Troopships and Isolated Medical Units

Units in this category need to be supplied with facilities for a small amount of transfusion work, which under certain conditions they may be forced to perform. To meet the needs of such units

the Box, Transfusion and Infusion, Field Pattern (1941) (Fig. 8) is issued. This contains :—

Dried plasma, bottles (400-c.cm.)	5
Distilled water, bottles (400-c.cm.)	5
Administration sets	5
Glucose saline, 540-c.cm. bottles	4
Administration sets	2
Bottles with equipment (1940 pattern) for taking and giving blood (complete)	2
Bottles, dispensing, screw cap, containing 100 c.cm. Sodium citrate solution, 3 per cent.	6
Dried grouping serum, ampoules 2-c.cm.	pairs 1

All components are replaceable after use by indent through the usual channels upon Base Transfusion unit (in the case of a main force overseas) or Army Blood Supply Depot at home, with the exception of equipment for the giving and taking of blood and the giving of glucose-saline, which is designed to be cleaned and used again.

NOTES CONCERNING PROCEDURES, EQUIPMENT AND MATERIALS USED IN RESUSCITATION WORK

Transfusion

General Principles

The *volume* of a transfusion for an individual case is governed by clinical impression supported by serial observations of the blood pressure. As a rough rule, 500 c.cm. of protein fluid is required to restore the blood pressure permanently to normal, for every 10–20 mm. Hg. that the blood pressure is reduced below normal. A number of features may disturb this rule. These include continued bleeding, which is suggested by failure to obtain the anticipated rise. A blood pressure reading, as a check both upon the sufficiency of the transfusion and upon overloading the circulation, is indispensable.

As to *rate*, it is generally safe to administer 500–1,000 c.cm. quickly to those whose systolic blood pressure fails to recover to 100 mm. Hg with the simple measures of warmth, rest and morphine. Thereafter, *rate* must be governed by results. Emphasis has already been laid on the necessity for maintaining the condition of the patient during operation, when the anæsthetic or loss of blood may lead to rapid deterioration (p. 6). A fast rate is not always well tolerated and may induce a rigor ; slowing of the rate abolishes this.

The volume of the transfusion as well as the *choice of fluid* depend greatly upon the amount of delay between wounding and receiving treatment.

Rapid Evacuation.—Casualties evacuated rapidly may still be alive despite having suffered huge losses of blood as well as gross reduction in systolic blood pressure, to 50 mm. Hg or less. Prompt treatment of these saves many lives that are ordinarily lost through the delay inevitable on a battlefield. Such casualties respond well to quick and quantitative replacement of the circulatory fluid lost,

because there has been no time for compensatory absorption of tissue fluid to occur—and indeed they would be incapable of living long enough for this mechanism to come into operation. Such casualties clearly require a large quantity of protein fluid which will remain in the circulation and promptly restore blood volume, blood pressure and circulatory efficiency. Blood, plasma and serum are all effective for this purpose, but the last two fluids have no oxygen-carrying power, so that when the transfusion needs to be massive it is an advantage for at least one pint in three to be of blood.

Delayed Evacuation.—When there is delay in evacuation (as in battle), those whose blood volume has been grossly reduced inevitably die. Those who survive have usually to some extent compensated for circulatory loss by absorption of tissue fluid. Hence the reduction in blood pressure is not usually so great as that found in the rapidly evacuated group, and the amount of protein fluid required to be transfused is correspondingly less. On the other hand, the degree of tissue dehydration caused by the compensatory absorption of tissue fluid is of a serious order and is associated with many of the symptoms (p. 6) found in secondary shock. Sweating, lack of water (especially in hot climates) and infection may also contribute to tissue dehydration. Administration of fluids by mouth, and of saline intravenously, is an important part of the treatment of such cases, and was found to be of great value in the 1914–1918 war. At that time the reason for the benefit was not clear, in that the blood volume reduction responsible for secondary shock had not been clearly differentiated from the tissue dehydration which is inevitable when the normal mechanism for blood volume replacement has had time to operate.

Equipment

The Army Medical Service transfusion equipment consists of a *Universal Pattern Blood Taking Set* (Fig. 10) and two patterns of administration equipment known as the *Overseas Pattern Giving Set* (Fig. 9) and the *Hospital* (1940) *Pattern Giving Set* (Fig. 10). These are illustrated and described in M.R.C. War Memorandum No. 1 already referred to, in addition to the various Emergency Medical Services patterns which differ in certain details.

(*a*) *Universal Pattern Blood Taking Set* (Fig. 10).—This consists of a two-holed rubber bung which will fit either the screw-cap or K.N.S. type of transfusion bottle. The bung, complete with rubber-tubing attachments, air-filter, glass window, intravenous needle with protecting glass tube, is issued wrapped in a calico envelope. After use the set should be immediately dismantled, cleaned and sterilized for a future occasion.

(*b*) *Overseas Pattern Giving Set* (Fig. 9).—This is designed to enable a transfusion to be given under the primitive conditions of active service. An administration set, sterilized ready for immediate use, wrapped in cellophane and contained in a tin box, is issued to the extent of one set for each two bottles of *stored blood* or *fluid plasma.* It is only necessary to remove the cap from the K.N.S. type bottle and perforate the tight-fitting bung with the

two stainless steel piercing needles of the administration set. The bottle is then inverted and hung up.

Dried Plasma is issued with a bottle of pyrogen-free distilled water for reconstitution. The administration set contains one of the special tight-fitting bungs which is inserted after reconstitution has been effected.

After use all apparatus of this type should be salvaged and returned to Base.

(*c*) *Hospital* (1940) *Giving Set* (Fig. 10).—This is for use in any place where *fresh blood* is taken from a local panel of donors and is designed to be cleaned and resterilized for repeated use. The principle is the same as the overseas equipment. Glass beads inserted into the bottle, take the place of the mantle filter of the overseas set while the bung is an ordinary two-holed rubber bung with glass tubes for air inlet and fluid delivery. The bung should be secured in place with a piece of strapping when the apparatus is in use. The same apparatus is used for *glucose-saline* administration but there is then no need to insert beads into the bottle.

A complete schedule of equipment issued by the Army Blood Supply Depot together with explanatory notes is given in Appendix (p. 48).

Blood

Blood, fresh or stored, is an excellent volume-restoring fluid and, when of reasonable age, the corpuscles of stored blood endure in the circulation of the recipient and contribute oxygen-carrying power. Old blood contains free pigment and numerous fragile corpuscles; the latter are rapidly destroyed when transfused. Such old blood gives rise to febrile and hæmolytic reactions, accompanied by jaundice. Blood, which is properly and cleanly taken into three per cent. sodium citrate solution to which has been added glucose (pure) to give a final concentration of 0·25–0·5 per cent. (40 c.cm. of a five per cent. solution to a 540-c.cm. bottle), and which is kept at a constant temperature 4–6° C., is well preserved for at least four weeks. After this time the blood should be regarded as " old " and, though usable in an emergency up to six weeks, is nevertheless liable to give rise to hæmolytic reactions. Blood up to 14 days' old has almost as much durable oxygen-carrying power as fresh blood.

Temperatures below 4° C. are far more deleterious to blood than are temperatures above 6° C. Low temperatures, particularly freezing, cause rapid hæmolysis. In cold climates it is sometimes necessary to place a hurrican lamp in a refrigerator in order to prevent freezing. Stored blood should be warmed to about 40° C. before being administered. This can be done by placing the bottle in a bucket of warm water. The spring of the metal cap should first be released, in order to avoid the danger of breakage.

The transport of blood presents problems under conditions of war. Slopping and frothing greatly hasten deterioration. To eliminate this trouble Army Blood Transfusion Service bottles are " topped " with a special machine and no slopping can occur. When a receiving unit is within reasonable road or air delivery distance of the Army Blood Supply Depot deliveries are made in special insulated boxes which keep the blood cool during transit.

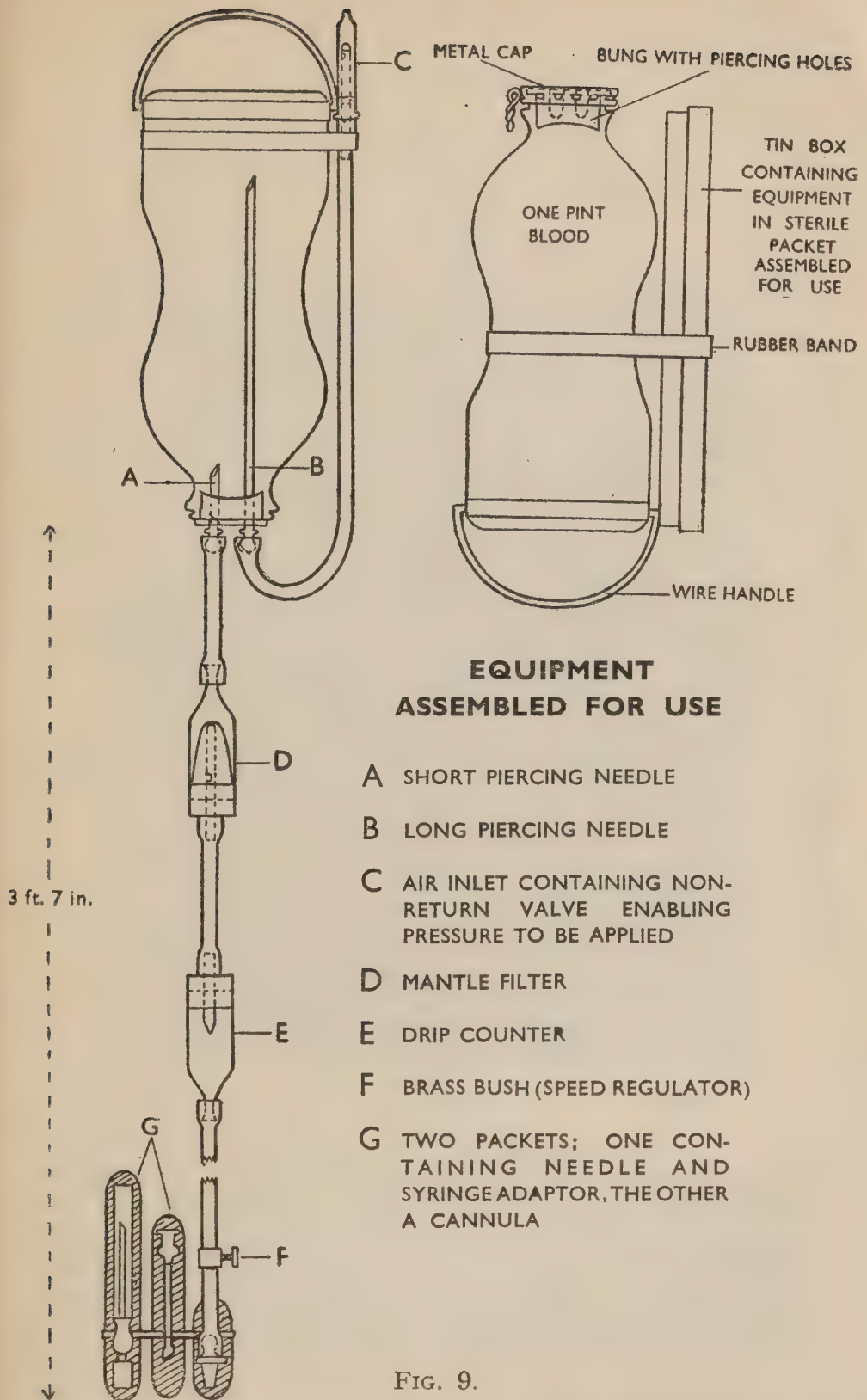

FIG. 9.

The Overseas pattern giving equipment (Code letter AA) for the giving of stored blood and fluid plasma obtained from Army sources. The bottle is the K.N.S. type which is sealed with clip cap. The bottle is corked with the special tight fitting white rubber flanged bung.

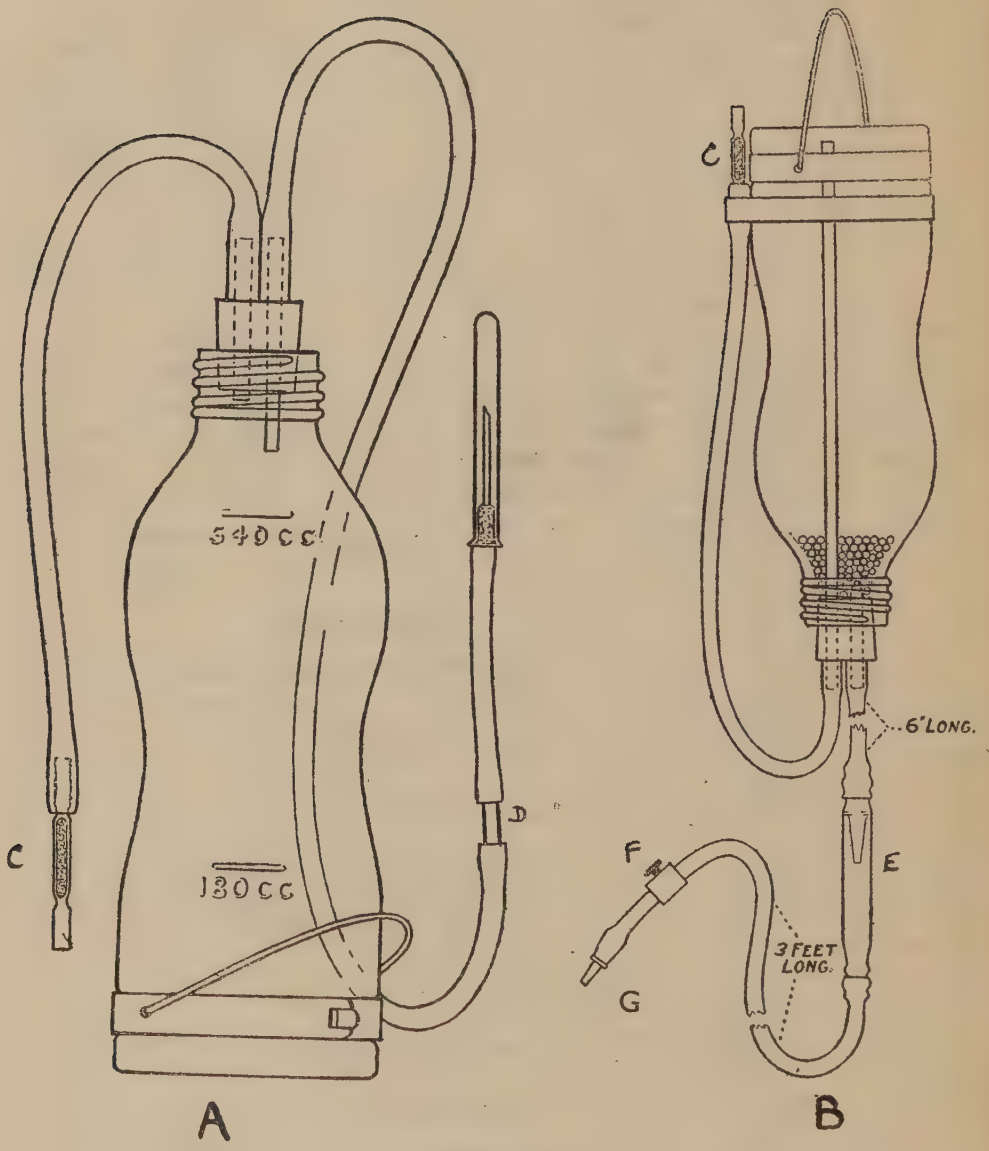

FIG. 10.

A. Universal pattern Taking Set (Code letter AF) assembled in screw-cap type bottle. C—air filter. D—glass window.

B. Hospital (1940) pattern Giving Set (Code letter AD) for administration of fresh blood and of blood or plasma supplied from E.M.S. sources. The same set is used for glucose-saline without beads. C—air filter. E—composite all glass drip counter. F—brass bush (speed regulator). G—tubing mount.

[*To face p.* 28

FIG. 11.

Apparatus Oxygen B.L.B. (Pattern B)

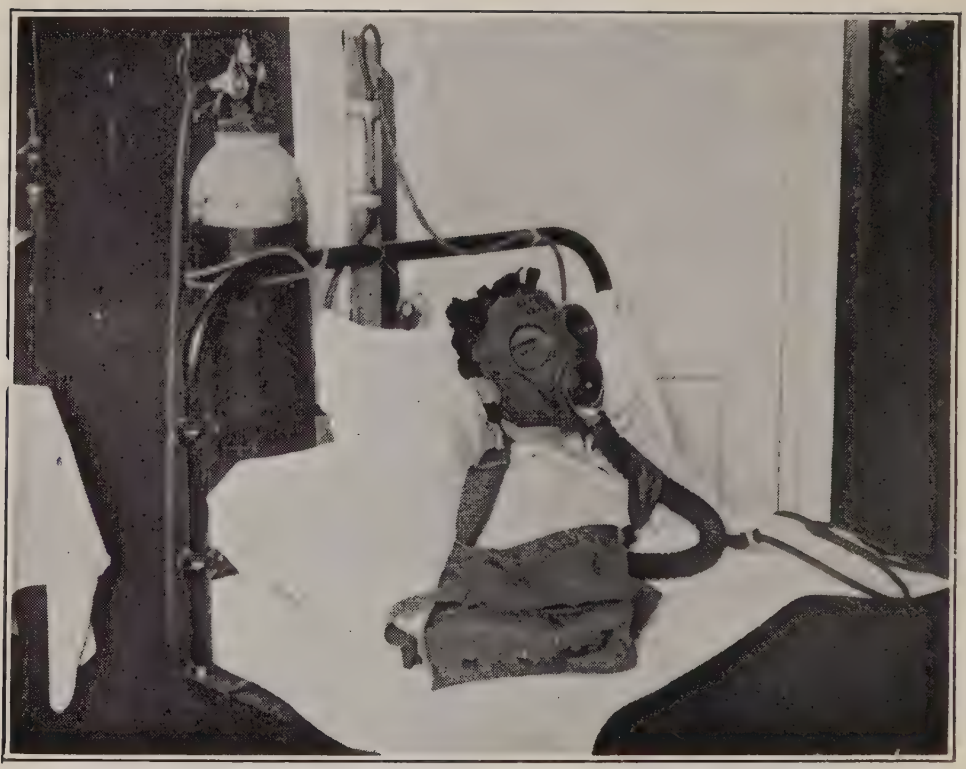

FIG. 12.
R.A.F. service respirator used as an oxygen mask.

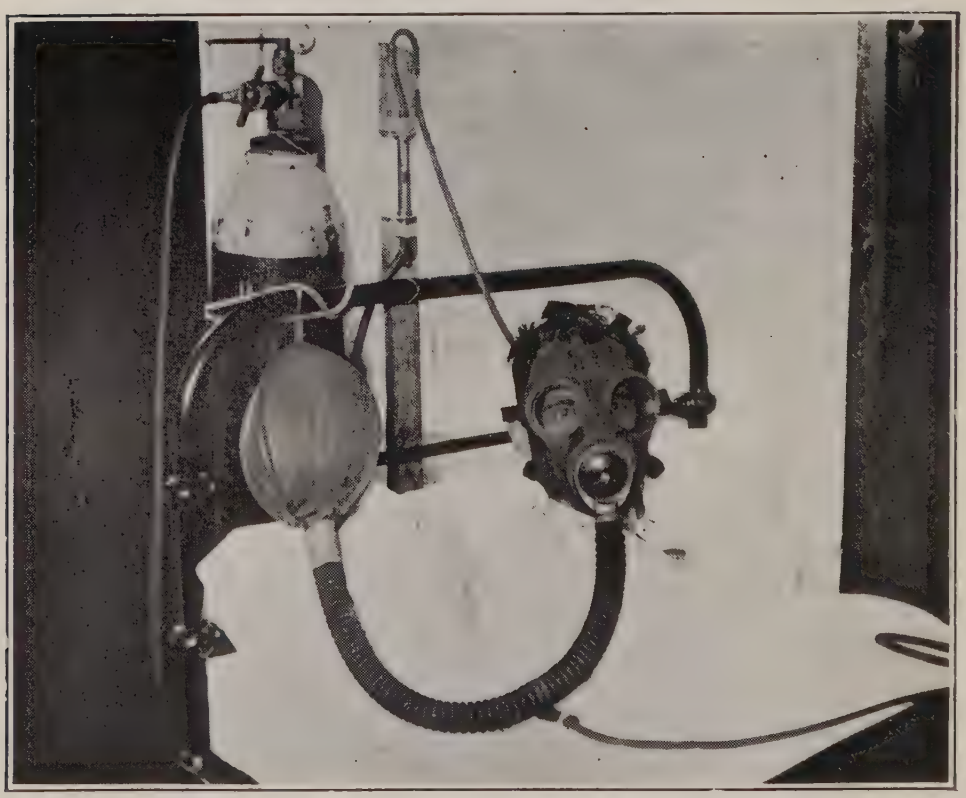

FIG. 13.
Method of administering high concentrations of oxygen with R.A.F. service respirator.

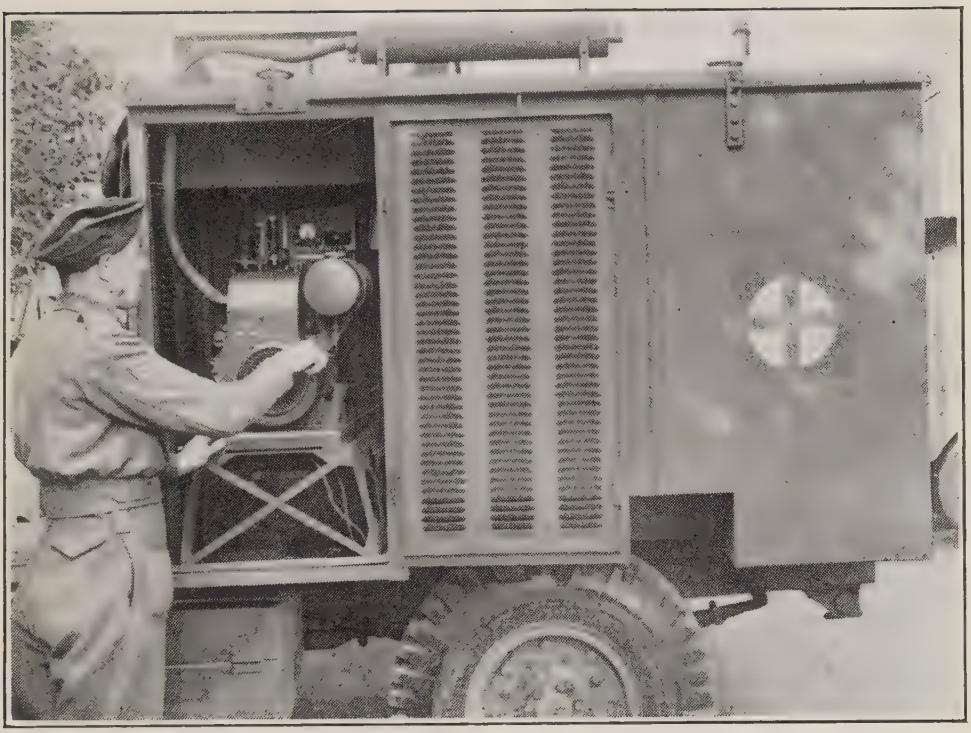

FIG. 15.

Starting the engine for the battery charging generator. (Type A refrigerator van.)

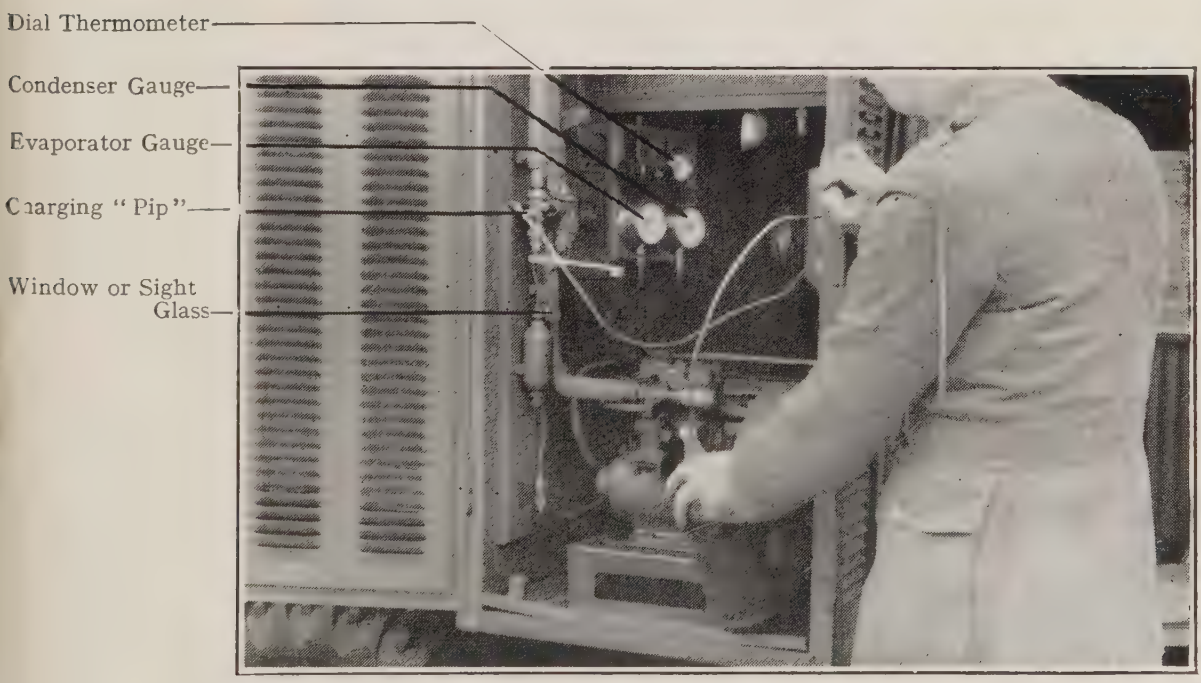

FIG. 16.

Maintenance of type A refrigerator. To show position of gauges and indicators. The operator has connected the methyl chloride gas cylinder to the charging pip.

Blood is the most physiological fluid for restoring blood volume in cases in which the reduction in circulating fluid is due to blood loss, in that there is the added advantage of oxygen-carrying power not possessed by blood derivatives, such as plasma or serum. When, however, blood volume has been seriously reduced by plasma loss, as with burns or with crushing injuries without much bleeding, the blood becomes viscid and concentrated, and in such cases the most physiological fluid is a non-cellular one, either plasma or serum ; the corpuscles of blood would be an additional burden to the circulation.

Blood supplied by the Army Blood Supply Depot contains 100 c.cm. three per cent. sodium citrate, 440 c.cm. blood and approximately 40 c.cm. five per cent. glucose ; it is all doubly checked Group O, Universal Donor, blood. Each bottle of blood is tested to exclude syphilis. This Universal Donor blood eliminates the necessity for a grouping test on the recipient. In cases where there is no emergency, and when facilities are available for grouping both donor and recipient, transfusions should be carried out with homologous fresh blood. This is especially desirable in medical cases.

Good quality stored blood has a sharp line of demarcation between the supernatant plasma and the corpuscles. The line is usually marked by a thin jelly-like clot (often called the " blanket ") composed of leucocytes and platelets. As blood becomes old, corpuscular pigment diffuses into the supernatant plasma, and blood in which a marked orange tint is obvious more than half-way up the plasma layer should be regarded as unfit for use. Contaminated blood is characterized by a complete diffusion of pigment throughout the plasma, and the colour is purple red rather than orange. Blood with a diffusely red plasma should never be used.

Fluid Plasma

Fluid citrate plasma is obtained by removing the supernatant plasma from blood taken in the proportion of 440 c.cm. blood to 100 c.cm. three per cent. sodium citrate. Plasma can be prepared from over-age blood in a blood bank and so avoids waste. A 540-c.cm. bottle yields about 200 c.cm., and it therefore requires the contribution of two to three donors to make 540 c.cm. of plasma. Furthermore, the plasma contains citrate solution in the proportion of two parts in seven and this is soon excreted when transfused. When estimating the amount that needs to be transfused for a permanent effect the volume of the citrate must not be counted, as it is only the water bound by the 4·5 per cent. protein which is retained in the circulation. Plasma prepared by the Army Blood Transfusion Service is rendered agglutinin-free by pooling the blood of heterologous groups and allowing a period of two hours for cross-absorption by the appropriate corpuscles, thus avoiding any danger of hæmolytic reaction in the recipient. After this, the plasma is separated, clarified of fat and passed through a bacterial filter before being finally bottled.

Citrated plasma in good condition is a clear golden or slightly orange fluid. When stored it has a tendency to deposit a small precipitate of fibrin, which does not render it unfit for use. Filtered

plasma may also contain clots, either massive or as small fibrin flakes. Provided that the surrounding plasma is still clear, these clots do not prohibit use, but it may be necessary to shake the bottle in order to aerate a large clot so that it floats and thus keeps clear of the outlet. Alternatively, the clot may be speared with the long piercing needle when this is inserted into the bottle. Infected plasma is always diffusely turbid and though turbidity may arise from a harmless cause, namely, incomplete removal of fat, it is safer to discard turbid plasma as unfit for use.

Cold storage in a refrigerator encourages the formation of clots, and bottles should therefore be stored at room temperature in the dark. Bright sunlight denatures protein and should be avoided. Properly stored plasma keeps at least twelve months.

Citrated plasma is an excellent and safe blood-volume restoring fluid for the treatment of secondary shock. It has no oxygen carrying power, and when a large transfusion is required it is an advantage for one pint in three to be blood. Plasma is particularly suitable for the treatment of burns, in which condition blood-volume reduction is due to plasma loss into the burned area. The resulting hæmoconcentration is best treated with plasma, controlled if possible by hæmoglobin estimation. Transfusion of whole blood tends to increase circulatory embarrassment.

Fluid Serum

Fluid serum is used for blood-volume restoration and for the treatment of burns in exactly the same way as plasma. It has no oxygen-carrying power and the same recommendation applies concerning the use of one pint of blood in three. Serum differs from plasma in that it contains no fibrinogen. The protein content is about seven per cent, and as serum contains no citrate it has a greater blood-volume restoring power than citrate plasma. Moreover, it is technically easier to prepare in a sterile filtered state than is plasma, and does not present the difficulty of post-filtration clotting. The yield per donor is approximately the same as with plasma. Danger of hæmolytic reaction from agglutinin content is overcome by pooling the serum until the titre has been reduced to a negligible point. On the other hand, there is much experimental and some clinical evidence to show that the incidence of reactions following massive transfusions is greater than with citrated plasma. More experience is necessary before the merits of the two fluids can be confidently assessed. Serum should be stored in a cool, dark place but there is no objection to storing in a refrigerator, except that the bottle has then to be heated before use.

Dried Serum and Dried Plasma

Drying is accomplished by a low temperature, low-pressure process which does not denature the protein. The dried product is reconstituted to its original volume by adding the requisite amount of pyrogen-free sterile distilled water (p. 34). Solution is effected in a few minutes, and the resulting fluid is somewhat turbid but this turbidity is normal and does not prohibit use. Once reconstituted the fluid should be used without delay otherwise the added water gives opportunity for any chance contaminating bacteria to

multiply to a dangerous degree. The reconstituted product should never be put away for future use, but in the dried state it keeps indefinitely without refrigeration. It was originally thought that serum reconstituted at quadruple strength would be particularly effective, especially with burns, in withdrawing plasma from an injured area and so contribute to blood-volume restoration, but experience has shown that such high concentrations of serum are associated with a large incidence of reactions. Reconstituted dried plasma or serum is an efficient blood-volume restoring fluid ; it is supplied in standard 540-c.cm. blood transfusion bottles which can be reconstituted to 400 c.cm. Under most service conditions the bottles of the dried product have to be accompanied by a bottle of distilled water suitable for reconstitution. The bulk to be transported is therefore almost double that with the fluid products.

Saline and Glucose-saline

Physiological saline (0·85 per cent.) is isotonic with blood and is the strength of saline ordinarily used for intravenous work. Hypertonic saline is of very doubtful value in resuscitation work. When the administration is made per rectum the strength of the saline should be half normal (0·425 per cent.). Five per cent. glucose (5 g. anhydrous glucose A.R. in 100 c.cm. distilled water) is isotonic with blood and is usually mixed in equal parts with 0·85 per cent. saline to make glucose-saline. Glucose-saline is obtainable on indent from Base Transfusion Unit (Overseas) or Army Blood Supply Depot, and is distributed in standard 540-c.cm. blood transfusion bottles. On active service administration sets accompany each pint bottle. At home hospitals the standard blood administration set, without bead filter, is used.

Taking of Blood for Immediate Use and for Store

When blood is taken for immediate use, minor contamination from air-borne bacteria is a negligible factor. But when blood is stored, even very small numbers of quite harmless bacteria lead to rapid deterioration and may multiply to a dangerous extent if the blood be removed from the refrigerator and allowed to reach a favourable temperature for a few hours. When blood is taken for store every precaution must be taken to avoid even the slightest contamination.

(*a*) *Taking Blood for Immediate Use.*—The apparatus consists of a screw-cap standard transfusion bottle, a " taking " bung with the appropriate attachments and a " giving " bung with its attachments, as well as beads to act as filter (Fig. 10). All of these have presumably been sterilized in advance and stored in tins or in a dust-free cupboard, or else covered with paper or cloth to prevent the settlement of dust. To the blood transfusion bottle add 100 c.cm. sterile three per cent. sodium citrate. After inserting the " taking " bung the apparatus is ready for use. Sufficient two per cent. procaine should be injected over the selected vein, for preference the median basilic. Skin contamination is rare if the needle is deftly inserted into the vein through the well-cleansed skin in a single operation. During the taking process an assistant

should rotate the bottle slowly, in order to ensure even mixing of the blood with the citrate. When the bottle is filled to the 540-c.cm. mark it is only necessary to pour in a test-tube full of sterile beads to act as a filter and change the " taking " bung for the " giving " bung, securing this in position with a little adhesive tape. The blood is then ready for administration.

(*b*) *Taking Blood for Store.*—It is necessary to avoid the minor air-borne contamination which occurs when a screw cap is removed from a bottle or a bung is inserted. It is therefore advisable to add the 100 c.cm. of three per cent. sodium citrate to the bottle and insert the " taking " bung as before and thereafter to re-autoclave the whole apparatus with bung *in situ*. The blood must then be cleanly and quickly taken. If it is proposed to store for more than a week, it is an advantage to add glucose to the extent of 0·25 to 0·5 per cent. The glucose solution has to be autoclaved separately from the sodium citrate (*vide infra*), and it is conveniently autoclaved as a five per cent. solution, either in a rubber-capped bottle or a metal screw-capped bottle, which is perforated to allow puncturing of the underlying rubber diaphragm. After removing the needle from the vein of the donor, wipe the needle with a swab soaked in spirit and then plunge it through the rubber cap or diaphragm of the bottle containing glucose ; elevate and invert the glucose-containing bottle and allow about 40 c.cm. of the solution to run in by gravity. This avoids all air-borne contamination. It is now necessary to change the " taking " bung for the metal screw cap of the bottle, which must be done neatly in the proximity of a flame after the manner of all bacteriological manœuvres. Alternatively the two pieces of rubber tubing connected to the " taking " bung may be clipped, or tied off, close to the bung. The bottle, with the screw cap or with the " taking " bung *in situ*, should then be placed in a refrigerator at 4–6° C., and not be removed until it is to be warmed ready for use.

Transfusion Reactions

1. Mismatched Transfusion

A frankly incompatible transfusion, *i.e.*, when the transfused cells are incompatible with the recipient's serum, usually gives rise to distressing symptoms after only a few cubic centimetres have been transfused. These symptoms include respiratory distress, rigors, pain in the back and vomiting, and may rapidly be followed by unconsciousness, with sudden collapse and death if the transfusion be continued. In other cases the initial symptoms may not be immediately fatal but there are later signs of the inevitable intravascular agglutination and hæmolysis, such as jaundice, hæmoglobinuria, embolic phenomena and urticaria. Death may occur within a few hours or a few days, from cerebral embolus or renal failure. This last has for long been attributed to blocking of the renal tubules with a pigment of the hæmatin order which is readily precipitated in an acid medium ; this leads to anuria and uræmia. The alternative explanation of the renal failure is that it is due to arterial spasm and ischæmia brought about by substances liberated from the destroyed corpuscles.

When such symptoms occur the transfusion should be stopped at once, whilst every effort should be made to alkalinize the urine and to promote simple diuresis, in order to facilitate the elimination of the pigment. Alkalinization also assists in the relief of arterial spasm. To ensure continuous alkalinity of the urine, as well as a good urinary output, a large amount of fluid and of alkali is required. The following treatment is appropriate :—

(*a*) *Oral Administration.*—8 g. (gr. 120) of sodium citrate *statim* followed by 27 g. (gr. 415) dissolved in 2,000 c.cm. of water flavoured with lemonade crystals during the following 24 hours. On subsequent days 35 g. (gr. 525) in 2,000 c.cm. fluid should be administered during each 24 hours until the urine is free of pigment. These recommendations for fluid intake are made on the assumption that the patient is deriving fluid from a normal diet, but failing this, an additional 1,000 c.cm. fluid in any acceptable form should also be taken. Unconscious patients may be given the same amount by stomach tube drip.

(*b*) *Intravenous Administration.*—As an alternative to the oral route, 150 c.cm. of three per cent. sodium citrate may be given intravenously by syringe, followed by 450 c.cm. of three per cent. citrate mixed with 2,400 c.cm. five per cent. glucose by intravenous drip during the following 24 hours. Subsequently the patient should receive, by intravenous drip, 660 c.cm. three per cent. sodium citrate mixed with 2,400 c.cm. five per cent. glucose every 24 hours until the urine is free of pigment.

An alternative treatment worthy of trial is the prompt transfusion of 200–300 c.cm. of compatible blood ; this is said to relieve spasm at once.

2. Mild Reactions

Reactions of a less serious nature following within a few hours of transfusion arise from a number of causes ; they may include fever, rigors, urticaria, jaundice, hæmoglobinuria, general malaise and sometimes an asthmatic attack. Jaundice and hæmoglobinuria are usual after the transfusion of old stored blood containing much free pigment or large numbers of fragile corpuscles. The treatment is the same as for mis-matched transfusion. Relatively mild, but similar, hæmolytic reactions may occur occasionally owing to high titre agglutinins present in the transfused blood, which may react with the recipient's corpuscles. Such reactions are theoretically possible whenever Group O blood is transfused to a heterologous group, but the chance of such a reaction is small, because the agglutinin titre is rarely high, whilst the diluting effect of the recipient's own blood immediately reduces the titre to a negligible level. Nevertheless, with a massive transfusion into a recipient whose blood volume has been greatly reduced by hæmorrhage, the titre of the agglutinins contributed may be within the active limits, and such a hæmolytic reaction is usually of the type with delayed symptoms. Serum and plasma transfusions carry the same risks unless precautions are taken to remove agglutinins by pooling or by absorption. The treatment is the same as for mismatched transfusion. Fever and rigors may be caused by unclean apparatus,

pyrogen-containing distilled water, hæmolytic reactions, or sometimes by blood taken from a donor soon after a meal, when a tendency to produce allergic manifestations is also said to be more common. Rigors are sometimes due to transfusions being carried out at too rapid a rate. In such cases a reduction in speed is almost immediately effective.

Preparation of Solutions for Intravenous Use

The three solutions mainly required are three per cent. sodium citrate, five per cent. glucose and 0·85 per cent. physiological saline. All of these are stable at autoclave temperature, provided the chemicals themselves are of fine quality. None but the A.R. quality of sodium chloride and dextrose should be used. Pyrogenic reactions occur when the distilled water used for solution has not been obtained from a still fitted with sufficient baffle plates to prevent the carry-over by splash of the bodies of fever-producing bacteria. The bacterial bodies constitute a foreign protein which induces a febrile reaction. Nevertheless, it is possible to render pyrogen-containing distilled water fit for use, whilst even a good quality ordinary boiled water can also be employed. Such waters may be cleared of bacterial bodies either by filtration through a Seitz filter, using an S.B. pad, or by sprinkling in finely powdered charcoal, which absorbs the bacteria; the charcoal is afterwards removed by filtration through ordinary filter paper. The charcoal is added in an amount of 1 g. per litre and is well shaken for 15 minutes.

Distilled water once made should be used immediately. Stale distilled water, however stored, is always exposed to air-borne contamination, which includes bacteria capable of multiplying even in this theoretically unsatisfying medium.

Solutions for intravenous use should be made with freshly distilled water and be distributed into their final containers; they should then be autoclaved immediately. If this is done the solutions keep indefinitely, but otherwise there is a great tendency for the solution (sodium citrate especially) to grow moulds. As with stored blood, the main principle is to allow a small number of air-borne contaminating bacteria no opportunity to multiply.

Care and Cleaning of Apparatus for Repeated Use

Pyrogenic reactions are caused as commonly by unclean apparatus as by pyrogen-containing solutions. Apparatus used for intravenous work must be scrupulously clean, and it is not always easy to ensure that glassware, rubber tubing and the other equipment used for transfusion work are thoroughly cleaned for repeated use.

As a general rule, the cleaning process should be started immediately after use, especially after transfusions of blood. A thorough soaking in clean, *cold* water is the first essential, as this dissolves pigment and loosens clots so that they can be easily dislodged. All apparatus should be dismantled and soaked in cold water for several hours. The bottles should then be washed in hot water, using a stiff test-tube brush to ensure thorough cleaning, whilst glass tubing can be cleaned with a pipe cleaner. Rubber tubing is best cleaned with a jet of hot water, by fixing the tubing on a dispenser's

tap. Failing this a 0·22 rifle pull-through brush or a stiff wire pull-through are quite efficient. Glass beads should be cleaned by swirling them in a tin with hot water so that the beads rub rapidly one against another. Needles should be cleaned out with a stilette and afterwards washed through with a jet of water from a syringe.

Thick rubber tubing can be autoclaved many times without deterioration, but thin tubing needs to be renewed after being used three or four times. In each case unfitness for use is shown by loss of elasticity. Rubber tubing should never be stored in rooms which are subjected to extremes of temperature.

Technique of Blood Grouping

Blood grouping is carried out with the sera of blood groups A and B, which contain the agglutinins β and α respectively. With these two sera it is possible to detect the four blood groups, according to the scheme set out below. In ordinary practice it is customary to mix a drop of each of the sera with a drop of the blood under test and to observe the occurrence or absence of the phenomenon of hæmagglutination. It should be borne in mind that the reaction is essentially a quantitative one and that easy reading is dependent upon a number of factors. In the first place, it is necessary for the test sera to be of high titre and also what is called " avid ". Such sera will cause a reaction, usually within one minute, whereas weak sera may take as long as an hour to react, and even then the agglutination may be so feeble that a microscope is necessary to detect it. This is especially so with subgroups A_2 and A_2B the cells of which are relatively insensitive to agglutination with α serum. Testing serum must be selected so that it will detect the insensitive A_2 factor otherwise serious errors occur. High titre serum may rapidly lose its power if improperly stored, exposed to sunlight or from a number of other factors, including the addition of antiseptics. Testing sera should preferably be frozen solid and kept in the dark, but as this is rarely possible under service conditions, grouping serum is now dried by a low temperature, low pressure process in which state it is preserved indefinitely without cold storage.

In the second place, the test needs to be arranged so that the serum has the greatest opportunity of action, and so that obscuring phenomena are reduced to a minimum. There should always be an excess of serum as compared with the corpuscles under test. In practice, these conditions are best achieved by diluting the test blood with saline, one drop of blood to about one c.cm. of saline. One drop of this saline suspension is mixed with a good sized drop of the test serum or with a pinch of the dried product. Dilution of the blood also reduces the amount of pseudo-agglutination (rouleaux formation) which occurs whenever blood is shed and which, if very marked, may be mistaken for true hæmagglutination.

When carrying out grouping tests it is advisable to test a number together rather than perform single tests, because the normal distribution of the groups (AB : 2 per cent., A : 47 per cent., B : 10 per cent., O : 41 per cent.) may then be observed and a rough check is available as to the suitability of the test serum. Thus, impotent serum, which fails to detect groups AB, A and B,

would erroneously indicate that all those tested belonged to Group O, whereas infected serum, which has pan-agglutinating properties, would suggest that all belonged to Group AB. Such results in a reasonable sized number of subjects under test would be so abnormal as to cast grave suspicions on the goodness of the test sera.

In relation to pan-agglutination it should be borne in mind that the fault may lie with the corpuscles under test as much as with the test sera, and that it is particularly likely to arise if the saline corpuscle suspensions are not tested when fresh but are allowed to lie about overnight or longer. An odd skin contaminant present in such a suspension quickly multiplies and so introduces this complication.

The following are the routine instructions issued with the dried grouping serum supplied by the Army Blood Transfusion Service :

Instructions for Blood Grouping

The equipment provided consists of an ampoule each of A and B dried serum, four microscope slides, china pencil, glass file, a needle and a lump of plasticine.

Methods.—1. The tops of the ampoules should be removed with the help of the glass file. If the dried serum is caked, it may be powdered by passing a flamed piece of wire into the ampoule and breaking up the serum. After use the ampoules can be sealed with a plug of plasticine.

2. A glass slide should be divided in two by a line, using the china pencil, and one end marked A and the other B. The donor's or patient's name should also be marked on the slide to avoid confusion, if two or more are being tested at the same time.

3. An amount, equivalent to the size of a match-head, of each of the dried sera should be shaken on to the appropriate end of the slide.

4. A drop of the prospective donor's or patient's blood, obtained by pricking either the finger or lobe of the ear and diluted in one c.cm. of saline, should then be mixed with each of the sera, and the slide gently rocked to and fro.

5. *The result* may be read in 6–10 minutes. If agglutination has occurred the red cells will be seen in clumps visible to the naked eye. If no agglutination has occurred, a uniform pink opacity remains in the drop. The glass slide should be viewed against a white background.

If agglutination occurs in A only the subject belongs to Group B (3).
If agglutination occurs in B only the subject belongs to Group A (2).
If agglutination occurs in A and B the subject belongs to Group AB (1).
If agglutination occurs in neither the subject belongs to Group O (4).

Note.—Group O blood may be safely given to a patient belonging to any of the four groups. Blood of Groups A, B or AB, may be given to patients belonging to the same group or to Group AB.

Principles Governing Fluid Administration for the Treatment of Dehydration

The condition of secondary shock is believed to be due mainly to reduction in blood-volume from blood or plasma loss. The natural protection in response to this loss is the absorption of tissue fluid into the circulation, resulting in hæmodilution. This process takes time to develop, but casualties who survive a serious blood loss and who are not attended for many hours, perhaps days, have inevitably suffered tissue dehydration from absorption of tissue fluid. This dehydration contributes to the symptoms of secondary shock. Eventually when tissue fluid reserves are exhausted, so that blood volume can no longer be maintained, the result is a circulatory state with a falling blood pressure essentially similar to, but, by reason of hæmoconcentration, even more serious than that found in secondary shock. The course of events is described below.

It will be appreciated that battle casualties who inevitably suffer delay in treatment are more prone to these complications than are air-raid casualties who are seen within a short time of wounding and in whom the protective hæmodilution or the even later phases have not had time to occur. Dehydration should therefore be especially considered in casualties whose treatment has been delayed, and resuscitation officers should appreciate the immense benefit of giving fluids by the mouth to such cases, as well as the value of supplementing this administration by the giving of crystalloid solutions (saline, glucose-saline) intravenously. Nevertheless an excess of such fluids by the intravenous route is dangerous, whilst crystalloid solutions have very little value for the permanent restoration of blood-volume, for which a protein-containing fluid is required. The treatment of dehydration should be designed to replace lost tissue fluid. The following notes present the principles governing saline and glucose administration :—

Dehydration

Dehydration is a state of bodily water depletion which arises when fluid intake fails to balance fluid output. Output continues even though no fluid is taken, the minimum daily loss from lungs, skin and urine being approximately three pints. In these circumstances, the tissues become desiccated. When tissue fluid reserves come to an end, the normal blood-volume can no longer be maintained, the blood becomes concentrated and viscid, and the blood pressure drops. The late stages are therefore not only desiccation of the tissues but also blood volume reduction with hæmoconcentration, causing a progressive circulatory embarrassment more serious than that produced by a primary hæmorrhage. Finally, the urinary output drops to less than a pint in 24 hours—an amount insufficient to excrete waste products. Consequently, "uræmia" and disturbance of acid-base equilibrium result, with delirium or other cerebral symptoms. A normal man deprived of water will die within nine days.

Importance of Dehydration in War Casualties

Since 1930 great advances have been made in the study of dehydration and its paramount importance has been realized. Observers

in the war of 1914–1918, noting the water depletion in the wounded, emphasized again and again the therapeutic value of copious drinks.

Under battle conditions, the soldier may be in a dangerous position where water rations are short. Sweating may increase his fluid output. He is potentially dehydrated before being wounded. His wounds may result in hæmorrhage, exudation, vomiting and further sweating and he may " lie out " unattended for some hours. When he is picked up, morphine, given to relieve his pain, may cause thirst to lose its insistence, and weakness may make drinking an intolerable effort. All these factors, acting together, can produce in a single day dehydration severe enough to render a man gravely ill, quite apart from the effect of his wounds. Too often, the symptoms are ascribed to shock or toxæmia, and treatment delayed.

Recognition of Dehydration

The earliest symptoms are thirst and weakness. The mouth becomes dry, the skin inelastic, and the expression sunken. Urinary output is low. At first the pulse and blood pressure are not affected, since the blood volume is maintained by absorption of tissue fluid, but later the pulse becomes thin and rapid and the blood pressure falls. When the blood becomes viscid, cyanosis develops. The clinical picture at this stage is indistinguishable from that of secondary shock. Death is sometimes preceded by a low muttering delirium.

Treatment of Dehydration

The degree of dehydration, which can be roughly gauged from the clinical features, influences the amount of fluid that needs to be administered as well as the choice of route.

Amount of Fluid.—From the symptoms the approximate amounts of fluid necessary for a given case can be estimated. Dry mouth and scanty urine appear when the water deficit amounts to six per cent. of the body weight—seven to ten pints for an average man. Low blood pressure, feeble pulse and cyanosis denote a deficit of at least ten per cent. of body weight—12 to 16 pints. To this figure must be added the normal output during the period of hydration, *i.e.*, five pints every 24 hours. In cases where abnormal losses occur through vomiting, exudation, etc., further addition must be made to the total.

The simplest criterion of adequate hydration is a urinary output of two to three pints every 24 hours.

Route of Administration.—This involves not only choice of route, but also selection of the fluid to be administered. Three routes are available : (1) oral, (2) rectal and (3) intravenous.

(1) *Oral.*—Fluids should be administered by mouth whenever possible. Patients too weak and exhausted to drink from glasses or cups will often consume large quantities when these are made easily accessible by a rubber tube running to their mouths from suitable containers.

As it is impossible to lose water from the body without also losing salts, the most important of which is sodium chloride, all drinks

should contain half a teaspoonful of sodium chloride to the pint. Such an amount is almost tasteless, but greatly enhances the value of fluid therapy.

(2) *Rectal.*—The rectal route serves as an adjuvant to oral administration of fluid. The fluid of choice is half normal (0·425 per cent.) sodium chloride.

(3) *Intravenous.*—Where oral and rectal administration are inadequate, intravenous administration is necessary. The volume of fluid given must be carefully measured. The continuous drip method should be used and a steady rate maintained which, in general, should not exceed one pint every two hours. A pint every four hours is more suitable for most cases (=40 drops per minute).

The choice of fluid lies between isotonic saline (0·85 per cent. NaCl) and isotonic glucose (five per cent. glucose). These solutions are supplied from Base Transfusion Units or Army Blood Supply Depots in pint bottles, sterilized, ready for use.

Saline is necessary so that the tissues may retain fluid, but when it is given in excess too much fluid is retained and the urinary output decreases. Pulmonary œdema may result. Every pint of saline, therefore, should be alternated or mixed with a pint of glucose solution. Only in cases where there is excessive loss of sodium chloride should this ratio be altered. In the past the terms " fluid " and " saline " have been used synonymously in relation to dehydration and this practice cannot be too strongly condemned. Massive infusions of saline are not without danger. Watch should always be kept for rales at the bases during intravenous administration.

When plasma proteins have been depleted by hæmorrhage, trauma or exudation, the circulation cannot retain fluid and there is particular danger of œdema, unless the administration of fluid is pursued with caution. In such cases, intravenous fluid therapy should be preceded by transfusion of whole blood or of plasma.

In cases of head injury, when intracranial pressure is raised, the administration of fluid and sodium chloride should be a matter of great care as some degree of dehydration may be desirable.

Prevention of Dehydration

More important than the treatment of established dehydration, is its prevention. Much so-called " shock " can be avoided by giving adequate supplies of fluid at the earliest possible moment, at Regimental Aid Posts, Advanced Dressing Stations, during ambulance and train journeys and at succeeding medical units.

It was found in the war of 1914–1918 that casualties who had bled were unable, for many days, spontaneously to replenish their blood-volume. If water was made available to these men, their blood volumes returned to normal quickly and the ill-effects of hæmorrhage disappeared. A wounded man requires about six to eight pints of fluid in the first 24 hours, and five pints every ensuing 24 hours, but this generalization makes no allowance for abnormal losses.

In forward areas, where casualties pass rapidly from hand to hand, it is impossible to measure fluid intake accurately. A great deal can be done, however, by insistence on copious and repeated

drinks being given to every casualty, save those with abdominal wounds and those who are unconscious. Such drinks must be easily accessible to the weak, who must be coaxed to take them. Whenever possible, warm, sweetened tea is desirable, and should contain, as stated above, half a teaspoonful of sodium chloride to the pint.

At every medical post or at halting places, small pails of fluid should be set beside the deposited stretcher. Each pail should be provided with two-feet lengths of rubber tubing to be used as "straws". The fluid levels in the pails should be below the level of the patient's mouth, in order to prevent the establishment of a siphon which might cause too rapid delivery leading to choking.

Methods of Arresting Hæmorrhage

Continuing hæmorrhage leads to progressive reduction in blood-volume, thereby increasing the symptoms of shock. The resuscitation officer should therefore be equipped to stop all external sources of bleeding by firm bandaging over a wide area, with forceps, with ligature or with a tourniquet. Bandaging is preferable to most of the recognized patterns of tourniquet. Unrevealed sources of bleeding must obviously be left until the patient reaches an operating theatre. All casualties to whom a tourniquet has been applied as a first-aid measure should have the wound inspected to observe whether the application has been efficient. In most cases it is not advisable, in a resuscitation ward, to remove a tourniquet from those whose limbs will obviously need amputation, even where it is surmised that bleeding will not recur. Removal of a tourniquet is always followed by plasma loss into the injured tissue, which may produce serious shock. There has been much controversy as to the proper use of a tourniquet; the modern view is that more harm than good often follows its use, as its application for any length of time allows no alternative to amputation. Many limbs that might otherwise be saved become devitalized by tourniquet apparatus. Firm bandaging with several layers of wool, not only at the site but also embracing and supporting the whole limb, is just as effective in arresting hæmorrhage and limiting plasma loss, and it allows the surgeon more scope for conservative measures.

Application of Splints

Pain and the local plasma loss caused by movement of a fractured limb greatly contribute to shock. Field Transfusion Unit officers are supplied with Cramer wire and cutting pliers with which to effect immobilization. Patients sent to the operating theatre with a drip transfusion in progress should have the arm immobilized if they are at all restless. Restless patients also need to be splinted during a transfusion.

Administration of Oxygen

General Principles

Oxygen therapy is essential for the treatment of anoxæmia, usually manifested clinically by cyanosis, which is found when there is injury to the respiratory apparatus from wounds, blast or gassing.

Furthermore, the treatment is of great value as a supplementary measure in secondary shock because, in this condition, stagnation of the peripheral circulation causes the blood to give up much oxygen to the tissues so that the blood returning to the lungs is abnormally depleted of oxygen. Inhalation of oxygen in high concentration greatly increases the amount available to the tissues. A face-piece apparatus is essential if sufficiently high concentrations of oxygen are to be obtained. Neither a nasal catheter, nor a nasal tube on Tudor Edwards' spectacle frames, nor, least of all, an open funnel, provide oxygen in a concentration sufficiently high to be really effective. The standard army issue is Apparatus, oxygen, B.L.B. pattern (Fig. 11), which consists of the following :—

Masks, B.L.B., Nasal (consisting of face-piece, valve, I.R. bag and tubing), Regulator, pattern A (consisting of fine adjustment valve, and bobbin-type flowmeter), or pattern B (consisting of reducing valve, flowmeter, and pressure gauge) with adjustable spanner. Box, to hold above.

Instructions for Use

Before attaching the regulator to the oxygen cylinder open and close sharply the valve of the cylinder to remove any dust or grit that might be present. Screw the regulator into the cylinder valve, tightening flynut of the regulator by leverage provided on the cylinder key.

Do not admit a sudden rush of oxygen into the closed regulator, *i.e.*, before opening the cylinder valve see that the outlet valve on top of the regulator is slightly open, then, having moderated the flow close the outlet valve on the regulator until ready to administer.

To start the flow of oxygen open the main valve of the cylinder. Adjust the mask to fit the face snugly but in a manner comfortable to the patient. The mask is properly adjusted when the reservoir-rebreathing bag dilates and contracts with each respiration. The flow of oxygen can then be finally adjusted according to the colour of the patient's face. Either a blue colour of the lips and face or grey ashen colour indicates the need for oxygen and the return of a normal colour indicates that sufficient oxygen is being supplied. The minimum flow of oxygen required to maintain the desired effect should be used.

The desired concentration of oxygen depends on the regulation of the flow of oxygen in conjunction with the adjustment of the airports by means of the rotating sleeve on the connecting-regulating device. For example, experiments have shown that for a large to medium sized man the alveolar oxygen percentage will be as follows :—

With the oxygen flowing at 3 litres per minute with 2 holes open —45–55 per cent.

With the oxygen flowing at 5 litres per minute with 2 holes open —65–75 per cent.

With the oxygen flowing at 6–7 litres per minute with no holes open—92–95 per cent.

With Pattern A the flowmeter tube on the regulator must always be used in a vertical position, otherwise it does not register flows

correctly ; as the pressure falls in the oxygen cylinder, so proportionately will the reading on the flowmeter, and a periodical adjustment of the flowmeter is necessary to maintain the flow of oxygen required.

To Sterilize the Apparatus

Remove the mask and bag from the connecting-regulating device and wash each part with soap and water ; rinse with clean water and boil for three minutes. All parts should be hung up to drain and dry. The utensil used for boiling should be equipped with a wire screen to prevent the rubber parts from coming in contact with the bottom which might be hot enough to cause damage.

No disinfectant or germicide should be added to the water as this may cause corrosion of the metal parts and damage to the rubber.

Adaptation of Respirators

Civilian and service respirators can be adapted for the administration of oxygen in high concentration or for the giving of oxygen in an atmosphere contaminated with poison gas.

The method recommended by the R.A.F. is shown in Figs. 12 and 13. The respirator is worn in the normal manner and a standard transfusion needle is inserted through the corrugated tubing of the respirator in the vicinity of the perforated tab, to which it can be affixed by a thread or tape. The needle is connected by rubber tubing to a flowmeter and thence to a cylinder of

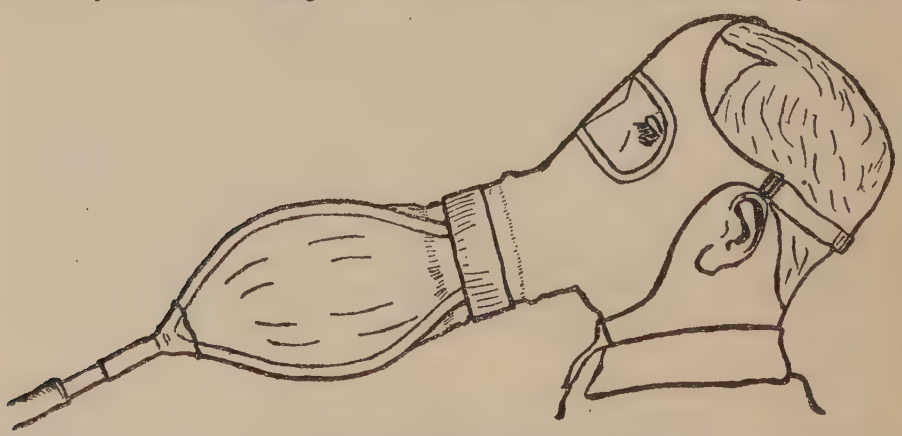

FIG. 14.—Civilian respirator adapted for oxygen administration in high concentration.

oxygen fitted with a fine adjustment valve ; the oxygen should be turned on so as to give a flow of six litres a minute. If it is decided to give pure oxygen a rubber rebreathing bag (such as is used for anæsthetic work), which will act as a reservoir (Fig. 13), may be substituted for the container of the respirator. The Army Service respirator, which has a shorter tube, can be used in the same way, the needle being inserted into the second corrugation above the container. The puncture can subsequently be sealed with adhesive tape.

The civilian respirator can be used on the same principle by inserting the needle through the rubber of the respirator. For high concentrations of oxygen the method devised by Marriott (1940, *Brit. Med. J.*, II, 519) is efficient. The only piece of apparatus necessary is a rubber football bladder (Association, size 4 or size 5). The bladder is fitted to the canister of the respirator by cutting a suitable sized hole in the bladder at the pole remote from the tubing inlet. The bladder is then stretched and slipped over the canister. The joint may be sealed more firmly with a rubber band. The inlet tube of the bladder is connected directly to the oxygen cylinder (Fig. 14). It is important to adjust the flow of oxygen so that the bladder is loosely filled at the end of expiration and half-filled at the end of inspiration.

Morphine

Relief of pain is of first importance to a wounded and shocked man. For this, morphine is of the utmost value and it is also useful for controlling restlessness. $\frac{1}{4}$ to $\frac{1}{2}$ gr. of the hydrochloride or tartrate salt is the usual subcutaneous or intramuscular dose. If a full dose is given a second dose should not be administered for at least four hours. When the circulation is feeble, and absorption consequently slow, an almost immediate effect of morphine can be obtained by intravenous injection. Up to $\frac{1}{4}$ gr. may be administered intravenously. The dose should be diluted to at least one c.cm. with sterile water and the injection made to occupy about one minute. All morphine injections should be clearly marked on the record card together with time of administration.

Anæsthetics

Efficient anæsthesia is of great importance in the injured. Gas and oxygen, with ether, if necessary, is the anæsthetic of choice. But there is a general impression that the anæsthetist will get better results with the anæsthetic to which he is accustomed than with some vaunted new preparation with which he is quite unfamiliar. Cyanosis must be avoided. Chloroform and spinal anæsthesia must not be employed. Pentothal has proved to be of value in cases of shock and hæmorrhage ; it has the advantage that it can be administered in the resuscitation ward, with no disturbance to the patient, by injecting the drug into the rubber transfusion tube towards the end of a blood or plasma transfusion ; the patient is unaware that an anæsthetic is being administered. Great care must be taken to limit the dose and to make the injection slowly, as these patients are extremely susceptible to barbiturates. A careful enquiry must also be made regarding the amount of morphia the patient has received and the time of the last injection. Patients previously treated with a sulphonamide compound also appear to require a smaller amount than usual. The usual five per cent. solution of pentothal is used and a dose of 0·3 g. to 0·8 g. will generally be sufficient to give adequate anæsthesia for an extra-abdominal operation. For intra-abdominal work a slightly larger dose may be required or the original dose followed by nitrous oxide,

oxygen and minimal ether. If pentothal is given alone, some apparatus for giving oxygen under pressure must always be at hand to deal at once with any signs of respiratory depression.

Prophylactic Chemotherapy

A resuscitation ward offers an opportunity for beginning or continuing a course of prophylactic chemotherapy. All treatment must be scrupulously recorded as to dose and time. For *local application* sulphanilamide is the drug of choice unless sulphathiazole is available, in which case a mixture of two parts of the former to one of the latter should be employed. From 5 to 15 g. should be applied as a fine powder according to the size and number of the wounds. The application should be made as early as possible and be repeated at the time of debridement. For *oral administration* a War Office Memorandum " Concerning the Use of Sulphonamide Derivatives " (September, 1940) recommends an initial dose of 1·5 g. sulphanilamide dissolved in hot citric acid or lemon in order to get rapid absorption, with subsequent doses of 0·5 g. starting two hours later and continuing at four-hourly intervals for four days ; all of these to be given as uncrushed tablets in order to obtain delay in absorption. If the beginning of the treatment has been unduly delayed or if the clinical condition gives reason to fear that gas gangrene is already beginning these doses should be, increased. Surgeons with experience of active service recommend as much as 4 g. for an initial dose with subsequent four-hourly doses of 1·5 g. for four to six days night and day. There is considerable scope for clinical judgment between the limits given above according to the nature of the wounds.

Care and Maintenance of Army Refrigerator Equipment

Types

Mobile Refrigerators are provided for home and active service use, and consist of :—

(*a*) Type A mounted on three-ton lorry, capacity 400 pint bottles in crates (Fig. 15).

(*b*) Type A modified, similar to the above, but provided with extra insulation for use as a cool room in tropical climates ; capacity 250 bottles in crates.

(*c*) Type B, mounted on 30-cwt. covered van, capacity 100 bottles not in crates, with or without tubes attached (Fig. 17).

(*d*) Type C, mounted on three-ton lorry, capacity 80 bottles not in crates, with or without tubes attached. Similar in design to Type B but has extra insulation for use in tropical climates.

Type C, being of universal application, is now the standard issue to Field Transfusion units on active service.

Principles of Refrigeration

All refrigerators in use with the Army Blood Transfusion Service work on what is known as the " Vapour Compression System ". The system employs a liquid under pressure which expands in the

cooling coils. During this expansion the liquid takes in heat from its surroundings and in so doing is converted into vapour. The vapour is then compressed and recondensed into a liquid ready for a further cycle.

The essential components of such a system are :—

1. Cooling coils or " Evaporator ".
2. Compressor, or pump, to extract the vapour from the evaporator and compress it.
3. Condenser, where the compressed vapour is cooled and subsequently liquified.
4. Regulator or pressure reducing valve which allows the correct amount of liquid refrigerant to re-enter the cooling coils.

Although the principle of the system is common to all, the application varies slightly with the different types.

Types A and A modified are fitted with a petrol engine, electric generator and storage batteries. The generating set, for battery charging, is driven by a small petrol engine that needs to be started by hand (Fig. 15). The refrigerating machinery, however, is driven by an electric motor which derives its power from the storage batteries and is entirely automatic in operation, stopping and starting as required by the temperature of the storage compartment. Cooling of the storage compartment is done by means of cooling coils arranged on one wall and a fan which circulates the air in the storage chamber over these cooling coils. Experience has shown that the most economical way of operating these types is to run the generating set as a daily routine for a period of time, sufficient to bring every cell in the storage batteries to full charge. The correct charging rate during this operation is 12 amps. The state of the battery is determined by use of the hydrometer supplied with the tool kit ; each cell should be checked in turn and when fully charged the reading on the hydrometer should be 1·285. The refrigerating machinery will then look after itself for the remainder of the 24 hours. In order to check the operation of the refrigerator a thermometer, two gauges and a window in the pipe from the condenser to the regulator are provided (Fig. 16). When operating normally the temperature of the storage compartment should be between 38° F. and 42° F. (Type A modified 55° F. to 60° F.). Evaporator gauge should read *approximately* 30° F. below the temperature of the van. The condenser gauge should read *approximately* 10° F. above the outside air temperature. The window in the liquid line should be clear and free of bubbles. The temperature scales on the gauges are the outside red figures, and it is important to note that gauge readings and the appearance of the liquid in the window are only significant when the refrigerating machine is running and has had time to settle down to normal working.

Types B and C have neither electrical apparatus nor any automatic instruments. The compressor is run by a small petrol engine which has to be started and stopped by hand as required. The cooling coils in these types do not cool the air in the storage compartment, but are immersed in a water jacket which surrounds it. When the machine is running the water jacket is converted into ice

and as soon as this is complete the machine can be stopped. The ice so formed gives a big reserve of cold. The ice jacket maintains a temperature of 4° to 6° C. within the cabinet.

These machines are also equipped with thermometer, two gauges and a window. The thermometer registers the temperature of the water in the jacket and is marked in the Fahrenheit scale. The temperature recorded when the machine is in use should therefore always be 32° F. (freezing point of water). As soon as the temperature begins to rise above this figure the machine should be started, but if it falls below this figure the machine should be stopped to prevent any under-cooling of the ice. When the machine is running and settled down the window should be clear and free of bubbles, the evaporator gauge should read 8° F. to 10° F. below the temperature of the water sleeve and the condenser gauge should read 25° F. to 30° F. above the temperature of the air being drawn over the condenser by the fan.

Maintenance

(*a*) *Types A and A modified :* routine points to observe at regular intervals :—

1. Acid in batteries of correct specific gravity and the level such that the tops of the plates are covered.

2. Oil in the engine sump completely changed once a fortnight. Level to be checked daily.

3. Generator and electric motor greased weekly.

4. Whole generator set complete with engine to be removed monthly, cover removed from generator commutator and inside of generator well cleaned.

5. Carbon brushes of generator, motor, condenser fan and evaporator fan to be checked monthly and replaced if worn to half their normal length. Commutator to be cleaned with rag dipped in petrol or fine glass paper.

(*b*) *Types B and C*

1. Level of oil in engine to be checked before starting. Oil to be completely changed once a fortnight.

2. Level of water in jacket to be checked weekly. Water must cover cooling coils ; these can be seen through the small plated inspection plate on top of the cabinet.

3. Condenser fins to be kept clean and free of dust.

Repairs

A small tool kit is provided, for such small running repairs as the R.A.M.C. orderlies are capable of doing. Major breakdowns or obscure troubles should be dealt with by R.E. personnel only.

The most common refrigerator troubles cause similar symptoms in all four types of refrigerator.

1. *Shortage of Refrigerant.*—The evaporator and condenser gauges appear lower than usual and bubbles are seen in the window

of the liquid line. The remedy is first to find the leak by means of the special test lamp provided and then to add refrigerant from the spare bottle until normal observations are obtained. To add refrigerant, attach the charging pipe supplied with the tool kit to the pip on the regulator stop valve and the other end of the pipe to the spare gas bottle, having first made sure that the stop valve is screwed out to its fullest extent. Having connected the pipe as above, screw in the stop valve spindle two full turns, open valve on gas bottle and start machine. Watch window and when it fills up shut off valve on gas bottle and leave machine running. Bubbles will probably reappear after a short while. Reopen valve on bottle and continue as before. Repeat this operation until the window remains full and the gauges show normal readings. Shut valve of gas bottle, screw out spindle of regulator stop valve to fullest extent, disconnect pipe, replace pip and valve stem cover (Fig. 16).

2. *Choked Liquid Strainer.*—Same signs as in 1, but in addition the small pipe from the liquid strainer feels colder than the large pipe from the condenser to the strainer. To remedy, screw in liquid stop valve as far as possible, run machine until evaporator gauge reads 2 lb. per sq. in. Screw in regulator stop valve spindle as far as possible, undo four nuts under the strainer and pull out the basket. Clean with petrol and finish if possible with methylated spirits. Replace strainer, slack off nut holding liquid line to regulator, open liquid stop valve, tighten up nut on regulator, open regulator stop valve, replace stop valve caps and start machine.

3. *Dirty Condenser.*—This will be indicated by higher condenser gauge reading than usual. Condenser fins should be thoroughly cleaned with brush or compressed air.

4. *Choked Regulator.*—The signs of this are as in 1 above, except that the window will be *full* of liquid. Proceed as in 2, but instead of removing strainer, remove regulator, clean with petrol and methylated spirits and replace.

In addition the Types A and A modified may develop some minor electric fault. The commonest are :—

1. *Main Fuse Gone.*—Replace and check compressor to see that it is not stiff, thus causing an overload.

2. Thermostat not working correctly. If temperature is above the limits given previously, remove cover from thermostat and see if the two points are making contact, if not, check the setting on the scale provided. If this is correct wedge the two points together and operate the machine by hand from the main switch until new thermostat is fitted.

3. Generator set will not record any charge on the ammeter. Remove fuse in switch box, examine and replace if necessary with 15 amp. fuse.

APPENDIX

SCHEDULE OF STANDARD EQUIPMENT OBTAINABLE FROM ARMY BLOOD SUPPLY DEPOT

General Notes

This list is compiled to assist in the composition of indents.

The code letters are designed to facilitate orders by telegram and to avoid ambiguity ; they should be quoted on all indents.

Telegraphic Address : TRANSFUSE BRISTOL.

Telegrams should give code letter first followed by number required, *e.g.* AA 50 VA 1 MC 100 would be interpreted as

Giving sets, overseas pattern : 50
Viscaps No. 1A : 1 tin of 5 gross
Adaptors : 100

STANDARD EQUIPMENT OBTAINABLE FROM ARMY BLOOD SUPPLY DEPOT

(A) Assembled Equipment

Code Letter	*Article*	*Notes*
AA	GIVING SET, OVERSEAS PATTERN, for use with fluid plasma or topped-up blood supplied from Army sources (Fig. 9, p. 27).	Issued with needle and cannula, wrapped in cellophane, sterilized ready for use and contained in gold lacquer tin box. Ordinary issue, one per two bottles of blood or fluid plasma contained in K N S type bottle corked with white flanged bung. Designed to be salvaged and reconditioned at Base.
AB	GIVING SET, OVERSEAS PATTERN, for use with dried plasma supplied from Army sources.	Same components, wrapping and tin box as above, with addition of one white flanged bung for insertion in bottle after reconstitution. Designed to be salvaged and reconditioned at Base.
AC	GIVING SET, HOSPITAL (1940) PATTERN, for administration of fresh blood or of glucose-saline, and of blood or plasma supplied from E.M.S. sources (Fig. 10, p. 28).	One unit consists of set complete with needle. Issued as : (*a*) Tin box containing six units (AC) each wrapped separately in calico envelope together with one cannula for each box, and glass beads.

(A) **Assembled Equipment**—*continued*

Code Letter	*Article*	*Notes*
AD	GIVING SET, HOSPITAL (1940) PATTERN—*contd.*	(*b*) Single unit complete with needle but no cannula, wrapped in cellophane, and glass beads (AD). Designed to be reconditioned for repeated use. Set will fit K N S or screw-cap type bottle. BOTTLES MUST BE INDENTED FOR SEPARATELY.
AE AF	TAKING SET, UNIVERSAL PATTERN (Fig. 10, p. 28).	One unit consists of set complete with needle. Issued as : (*a*) Tin box containing six units wrapped separately in calico envelope (AE). (*b*) Single set wrapped in calico envelope (AF). Designed to be reconditioned for repeated use. Set will fit K N S or screw-cap type bottle. BOTTLES MUST BE INDENTED FOR SEPARATELY.
AG	TAKING AND GIVING, COMBINED BOX.	Tin box containing two each of Hospital (1940) Pattern Giving Set and Universal Taking Set. Issued as part of the equipment contained in "Box Apparatus Transfusion and Infusion. Field Pattern."
AH	TRANSFUSION AND INFUSION APPARATUS. FIELD PATTERN BOX (Fig. 8, facing p. 20).	Issued to Field Ambulances, Troopships, Hospital Trains. (For contents *see* p. 24.)

(B) **Component Parts of Assembled Equipment**

Giving Sets, Overseas Pattern (AA and AB)

MC	Adaptor.	
RA	Bands, elastic, for attaching to bottles.	Issued as 1 lb. box (approx. 170 a box).
RB	Bands, elastic, for holding calico wrapping.	Issued as 1 gross.
CPD	Box, tin, gold lacquered.	
RE	Bung, white flanged, BT4A.	Issued with each bottle of Dried Plasma.
MA	Bush brass (speed regulator).	
CPK	Calico, for wrapping steel parts.	Issued as packets of 4 yds. × 36 in.
ND	Cannula, Blood Transfusion	
CPJ	Cellophane, for wrapping.	Issued as Sheets. One sheet a set.

(B) Component Parts of Assembled Equipment—*continued*

Code Letter	*Article*	*Notes*
AK	*Drip Counter, assembled, complete, consisting of:*	
RD	Bung BT5, 1 × 5 mm. hole.	
GA	Filter, cover, glass.	
GC	Tube, 2-in., shaped glass.	
VA	Viscap No. 1a.	Issued in tins containing 5 gross.
AJ	*Mantle filter, assembled complete, consisting of:*	
RD	Bung BT5, 1 × 5 mm. hole.	
GA	Filter, cover, glass.	
MF	Mantle.	
GB	Tube, glass, with lateral hole.	
VA	Viscap No. 1a.	Issued in tins containing 5 gross.
NC	Needle, Blood Transfusion.	
NB	Needle, piercing, long.	
NA	Needle, piercing, short.	
RJ	Tubing IR, ¼-in. with ⅛-in. bore.	4 ft. 1 in. a set (including 6 in. required for non-return valve).
MB	Tubing mount.	
AL	*Valve non-return, assembled complete, consisting of:*	
RF	Dam rubber.	Issued in tins containing 12 yds.
GD	Filter, air, enclosing.	
GE	Tube, glass, with side holes.	
VB	Viskring No. 00.	Issued in tins containing 10 gross.
MG	Wire, copper, for binding joints.	Issued as reels by weight 1 lb.
	GIVING SET, HOSPITAL (1940) PATTERN	
MC	Adaptor.	
GJ	Beads, glass, for filter.	One test-tube full (½ oz.) a set 10 lb. = 320 sets.
CPE	Box, tin, slip lid, for containing units of 6.	
RC	Bung BT3, Red, 2 × 5 mm. holes.	
MA	Bush brass (Speed Regulator).	
ND	Cannula, Blood Transfusion.	
GK	Drip counter, composite, all glass.	
CPL	Envelope, calico, for wrapping.	
GH	Filter, air-inlet.	
NC	Needle, Blood Transfusion.	
GG	Tubing, glass, fluted, 2½-in. lengths.	
GF	Tubing, glass, 9½-in. lengths.	
RJ	Tubing, IR, ¼-in. with ⅛-in. bore.	4 ft. 1 in. a set (including 6 in. required for air filter).
MB	Tubing mount.	

Taking Set, Universal Pattern

Code Letter	*Article*	*Notes*
CPE	Box, tin, slip lid, for units of 6.	
RC	Bung, IR, Red, 2×5 mm. holes.	
MD	Clip Mohr's.	Optional; 2 a set. For use with large bleeds.
CPL	Envelope, calico for wrapping.	
GH	Filter, air-inlet.	
NC	Needle, Blood Transfusion.	
GL	Test-tube, 2½ in. × ½ in., cover for needle.	
GM	Tubing, glass, 2½-in. lengths.	3 a set; one for window; two for bung connections.
RK	Tubing, IR, $\frac{7}{16}$-in. with $\frac{3}{16}$-in. bore.	2 ft. 6 in. a set.

(C) **Equipment—Separate Entities**

BA	Bottles, Blood Transfusion, K N S type.	Used for blood, fluid plasma and glucose-saline prepared at Army Blood Supply Depot or Base Transfusion Units. Not recommended for ordinary medical unit's own use.
BC	Caps, clip, for bottles K N S.	
BF	Bands, for bottles.	
BB	Bottles, Blood Transfusion, screw-cap type.	Used for dried plasma, distilled water for same, and recommended for ordinary medical unit's own use in taking and giving of blood.
BF	Bands, for bottles.	
BD	Caps, screw, aluminium.	
RG	Discs, IR, Red, $1\frac{7}{16} \times \frac{3}{16}$ in., for screw caps.	
CPG	Boxes, Insulated, with Ice-Insert, for Air Transport.	Ordinarily issued only to Base Transfusion Units and F.T.Us.
CPH	Ice-Inserts, spare.	Ordinarily issued only to Base Transfusion Units and F.T.Us.
ND	Cannula, Blood Transfusion.	
BE	Caps, screw, aluminium, perforated.	For use with dried plasma.
CPF	Crates, wire—to hold 10 bottles.	Ordinarily issued only to Base Transfusion Units and F.T.Us.
RH	Discs, IR, white, 25×2·5 mm.	For use with K N S type bottle by Army Blood Supply Depot and Base Transfusion Units when preparing glucose saline.
NC	Needle, Blood Transfusion.	
ME	Stands, transfusion, telescopic	For suspending transfusion bottles. Ordinary issue: Field Transfusion Units, 6; Military Hospitals, 3 per box of 12 taking and 24 giving sets.
VD	Viscaps, transparent, red, No. 5.	Used by A.B.S.D. and Base Transfusion Units for sealing plasma bottles.
VC	Viscose caps, No. 5, white	Used by Army Blood Supply Depot and Base Transfusion Units for sealing blood taking bottles for extensive bleeds.

(D) Products and Packing

Code Letter	*Article*	*Notes*
TIA	Blood, pint bottles	Indents should state with or without giving set (AA).
TIE	Glucose-saline, isotonic, pint bottles.	Indents should state with or without giving set (AD).
TIC	Plasma, dry, pint bottles ..	Indents should state with or without giving set (AB) and with or without distilled water (TID).
TIB	Plasma, fluid, pint bottles ..	Indents should state with or without giving set (AA).
TIL	SERUM, high titre, Group A : Dry, 2-c.cm. tubes	For blood grouping tests. Stable without refrigeration. Always issued to overseas units.
TIM	SERUM, high titre, Group B: Dry, 2-c.cm. tubes	
TIG	SERUM, high titre, Group A : Fluid, 5-c.cm. bottles	For blood grouping tests. 1 c.cm. sufficient for 30–40 tests. Fluid product needs to be used quickly or else stored in refrigerator.
TIH	Fluid, 10-c.cm. bottles	
TIJ	SERUM, high titre, Group B : Fluid, 5-c.cm. bottles	
TIK	Fluid, 10-c.cm. bottles	
TIF	Sodium citrate, 3 per cent., 100-c.cm., in specially treated 4-oz. med. flat.	For blood taking bottles.
TID	Water, distilled, 440-c.cm., for reconstitution of dried plasma.	

Packing

CPA	Boxes, wood, L. 27½ in., D. 11½ in. W. 15 in. ; 14 compartment for plasma.	Weight, filled, 56 lb. Weight, empty, 19 lb.
CPB	Box, wood, L. 29¾ in., D. 9½ in., W. 10½ in., Field Pattern, for Apparatus, Transfusion and Infusion (AH).	Weight, filled, 86 lb. Weight, empty, 30 lb.
CPC	Case, war, 3½ cu. ft. : L. 26 in., D. 16½ in., W. 14 in., for taking and giving sets issued to Military Hospitals.	Weight, filled, 54 lb. Weight, empty, 20 lb.

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Printed under the Authority of HIS MAJESTY'S STATIONERY OFFICE
by William Clowes & Sons, Ltd., London and Beccles.
(1874) Wt. 588—8504. 16M. 7/42. W. C. & S., Ltd. **Gp. 395.**
S.O. Code No. 57–566–0–42